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COVER PHOTOGRAPH

Dr. Vincent Schaefer's Yellowstone Field Research Expedition provided the setting for the cover photograph. The scene is near Seismic Geyser about two miles below Old Faithful Inn. The area offers many unique phenomena for outdoor laboratory experiments in weather modification.

WEATHER MODIFICATION ASSOCIATION

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AFTER A QUARTER CENTURY

by

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Twenty-five years ago as I struggled up out of Tuckerman's Ravine on the east side of the summit cove of Mt. Washington in New Hampshire in the company of Dr. Irving Langmuir, little did I realize that at a later date I would recall that climb with a sense of wonder. As we reached the top of the right gully along the rocky spur called "Lion's Head," a single snow pellet fell between us from a cap cloud which hid the Observatory on the summit of the mountain. As we paused to gain our breath and to put the climbing skins on our skis for the final ascent of the mountain, Langmuir pointed out the implications of observing that single particle of graupel. He mentioned that apparently the cap cloud was completely supercooled except for the very few nuclei for ice particle formation which accounted for the isolated graupel particles which were then falling. He also pointed out that the concentration of ice nuclei at that particular time was of the order of one per thousand cubic meters!

Four years later after I established the routine measurement of ice nuclei at the Mt. Washington Observatory, (still underway!) [1] we occasionally found the concentration of such particles would reach or even exceed one per milliliter. Thus we discovered a natural phenomenon which varied by a factor of a billion!

Snow is a phenomenon of basic meteorological importance in all parts of the world. I have flown through a heavy snow storm at 30,000 feet above the equator and made stereo photographs of the ice fields on Kilimanjaro and Mt. Kenya in that same region of our planet. Not only is snow of prime economic importance as a source of irrigation water in the summertime, but it also plays a collective and critical role in the air as it becomes involved in the dynamics of all large storms.

We are now beginning to recognize the snow particle for its important role as an air cleansing agent in which it removes pollution particles from the atmosphere through the mechanism of Stefan flow and by the fact that certain types of man-created pollution particles actually serve [2, 3] as very effective ice nuclei.

A TENDENCY TOWARD DECREASED EFFECTIVENESS

As I watch the development of weather modification activities in the United States, I become increasingly dismayed at the lowering efficiency and effectiveness of some of the field operations which are underway. In trying to discover the reason for this disturbing situation I am becoming convinced that there are a number of pertinent reasons for this occurrence. They are as follows:

Partial Education:

For the past twenty-five years there has been an increasing tendency on the part of students (and faculty) to become obsessed with the importance of theoretical and thus

computerized explanations of atmospheric processes. In some instances this has advanced to the point where there is a tendency to believe the results of the computer rather than the evidence presented by the actual weather system! The more serious aspect of this phase of education is that it tends to relegate the acquisition of atmospheric data to automatic sensing systems which also may be failing to truly measure the actual atmospheric processes they are designed to monitor. If the individual researcher is not a competent field man, highly skilled in extracting quantitative information from the real atmosphere, errors can readily become compounded to the point where the mechanism being studied has no relevance whatever to the problem under consideration.

The Desire for Comfort:

There is also the question of comfort. It is much easier and more convenient to sit at a desk in the sanctuary of the university, the research institute, or the federal office, and to speculate about atmospheric processes, than it is to encounter the real atmosphere during a turbulent plane ride through a thunderstorm, on the wind-swept summit of a mountain top or the blizzard of a driving snow storm. Many people don't like such an environment and are not equipped mentally or physically to extract meaningful data from the atmosphere on such occasions, or even to design reliable and weatherproof instruments to measure atmospheric parameters in an effective manner.

The Lack of Basic Practical Knowledge:

Since most of our current group of students in science come from an affluent urban environment, many of them lack even the basic survival instincts which were the common heritage of the young person who was nurtured and by an almost osmotic process acquired basic knowledge about the environment by growing up on a farm, a ranch, or even in a small town. As a youngster he had to do all manner of things which taught him self-reliance, self-imposed discipline, mechanical skills, the adjustment to the outside weather, and other such simple but very basic things which constituted the way of life of those times, and which was an extremely important phase of education.

The effect of science and technology on this way of life has been profound. Because it has been gradual rather than cataclysmic there are very few of us in the university who even recognize that many of our students have very serious gaps in their basic knowledge. Until we recognize this fact and intentionally plan to do something about it, I fear that the product of our graduate schools will be ill equipped to solve many of the simple but highly practical problems which they will encounter in their attempt to operate effectively in observing and understanding things that happen in the real atmosphere.

Individual Involvement with the Atmosphere:

There is nothing like first-hand experience to understand some of these factors. Some years ago I suggested [4] that no person should receive a doctorate in the atmospheric sciences without having spent a period of several months at a mountain observatory, or some similar location, where he was obligated to obtain useful and reliable information under fairly primitive conditions. I am now convinced that this was a sound proposal but there are still only a few universities in the world where such requirements are part of the required essentials for this advanced degree. In fact, I am afraid we are actually losing ground! There is now a tendency to rely on the so-called sub-professionals to do the field-work while the project scientists and their associates puzzle over the incomplete and sloppy field notes taken by someone who had little interest in carrying out

his assignment, and less understanding as to what it was all about!

A Common Obstacle to Weather Measurement:

There is a strange fascination about making weather measuring instruments automatic before there is an adequate understanding of the phenomenon to be recorded. Nothing is more useless or frustrating than a piece of mechanical or electronic gear with its shiny parts, blinking lights and push buttons, which operates for a few minutes until it gets hot or cold, or jams, or the ink freezes or refuses to run, the power fails, or the oil freezes, or the wind blows it away, or leaking water shorts the circuit!

I speak with some feeling because I too have from time to time followed that rosy path and succumbed to the promise of automatic equipment before I was ready for it.

As I have said frequently in the past -- there is yet no computer that can replace the human brain, no electronic circuit that can substitute for a pair of intelligent eyes, no mechanical device that can replace clever fingers. Of course, our technology if properly used can extend these facilities to fantastic degrees, but in the final analysis, it is the human mind which must consider, evaluate, hypothesize, propose and conclude if we are to make real progress. This is particularly true in the atmospheric sciences where so many diverse disciplines must be blended and harmonized if we are to solve our problems.

The Need for Better Popular Education:

We have a fantastic job to do in the field of popular education, otherwise the "people problem" will become insurmountable. There is already an attitude abroad that there are vested rights to the atmosphere and that natural phenomena such as "weather" should not be tampered with under any circumstances. This public attitude has recently been observed in the Northeastern United States in a region where pollution has already made noticeable changes in the cloud types which commonly occur.

A New Direction for Education:

I am thoroughly convinced that one of the most important things we can do at the present stage of our scientific and technological status is to devise effective methods to get young people to think for themselves. It is no longer possible to obtain an encyclopedic knowledge of even one narrow discipline. Thus it is essential that the well educated individual become one who not only knows how to size up a new problem but is versed in the procedures necessary to acquire the pertinent knowledge, and then has enough experience to proceed toward a workable solution.

If we in the atmospheric sciences can impart some of this philosophy to our younger colleagues, if we personally are willing to spend long and often tedious and uncomfortable hours in communion with the real atmosphere, and have the intestinal fortitude to withstand criticism when we know from first-hand experience that we are closer to the truth than our critics -- then, but only then -- will we make substantial progress in the field of weather control.

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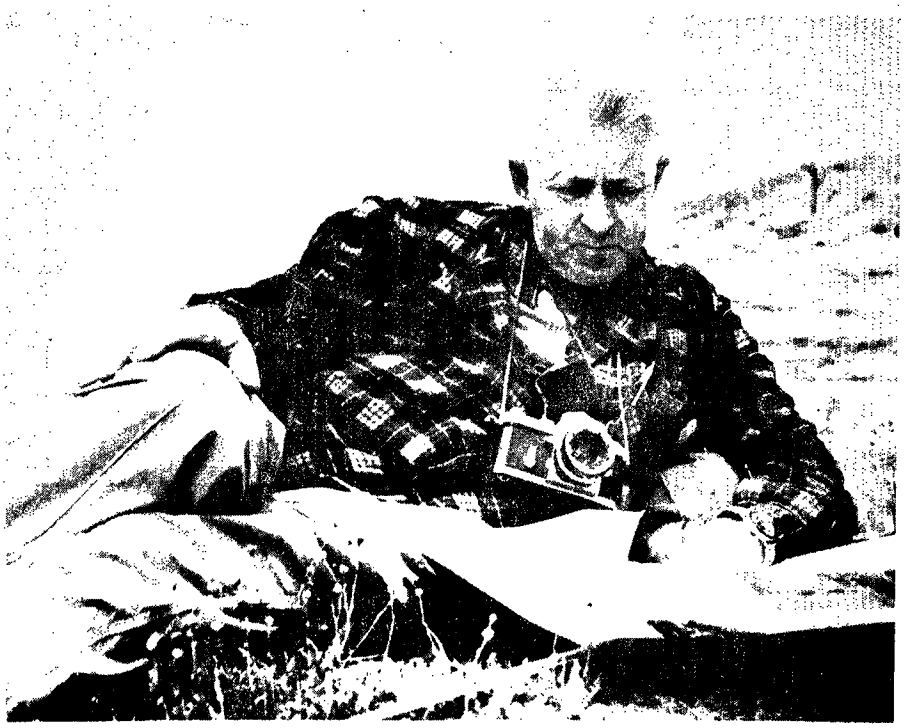

V. J. Schaefer

WEATHER MODIFICATION IN THE BUREAU OF RECLAMATION

by Archie M. Kahan *

Historical Development

The Bureau of Reclamation's Atmospheric Water Resources Program came into being late in 1961 when the 87th Congress inserted into the fiscal year 1962 Public Works Appropriation $100,000 "* * * to be used for research on increasing rainfall by cloud seeding." This appropriation stemmed from a conversation between Commissioner of Reclamation Floyd E. Dominy and the late Senator Francis Case of South Dakota. Senator Case asked Commissioner Dominy if the Bureau of Reclamation would be interested in developing weather modification into a usable tool for water resources management. The Bureau accepted the challenge.

The object of Project Skywater, as the Bureau's atmospheric water resources program is now called, is to develop the technology for enhancing the nation's water supplies through precipitation management. This operational goal goes beyond the ability to achieve an average precipitation increase from seeding a number of clouds. Operational capability implies the ability to determine ahead of time with a high level of confidence how a given storm would react to treatment, plus the ability to treat suitable storms in such a way that the effects are confined to a predetermined area.

While the physical mechanisms of precipitation formation were not completely understood when the program began, ample evidence was available, largely from the successes of private operators, to justify a practical research program aimed at learning how best to use weather modification techniques for increasing inflow into reservoirs. The first contracts were let with the South Dakota School of Mines and Technology and the Universities of Nevada and Wyoming. The University of Nevada was already involved in a field experiment and the Bureau of Reclamation provided additional support. The South Dakota and Wyoming groups began studies of summer cumulus and winter cap clouds, respectively. These were the only major contracts for the 3 years FY62, FY63, and FY64. In fiscal year 1964 the Bureau began studies of programs for the Southern Sierra region of California and Upper Colorado River Basin near the Continental Divide. The research in these early years identified many of the major gaps in the technology available at that time, and plans were made to fill them.

The first expansion of the program came in fiscal year 1965 when Congress appropriated $1,100,000, and Senate Report No. 1326, 88th Congress, stated, "The increase (over the budget request) is to be divided between research on orographic and convective weather systems. Emphasis is to be placed on actual water production and the exploration and

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research is to include application of existing weather modification methods." Projects were started not only in the Southern Sierra and Upper Colorado River Basin but also in the Wasatch Mountains, Arizona, and Washington. In addition, the Weather Bureau, the Forest Service, the Soil Conservation Service, the Geological Survey, and the Naval Weapons Center (then called Naval Ordnance Test Station) became involved in the program. The original contractors were able to expand their programs as well. In late 1964, the Bureau of Reclamation's Office of Atmospheric Water Resources was formally established in the Office of Chief Engineer in Denver to take care of the major expansion of the program.

In fiscal year 1966, the Senate recommended a $2.5 million increase over the budget estimate, of which $500,000 was for application of existing weather modification for the actual production of water. The House did not favor such a large increase, nor did it approve of the operational provision. The Conference Report (No. 1163, 89th Congress) suggested an increase of $750,000 and stated that, "None of the latter increase is to be used for application of existing weather modification methods for the actual production of water." The $2.98 million appropriated for FY 1966 permitted still more expansion. Non-field studies increased and included cloud physics research, instrumentation development, synoptic climatology studies, and development of evaluation techniques. Each of these efforts was directly related to the practical goal of getting more water on the ground. As is typical of the earlier years of any major research program, new questions were uncovered with greater frequency than old questions were answered.

Some in the scientific community suggested that the number and complexity of the questions being raised argued in favor of a slowdown, if not a moratorium, for field projects while laboratory and computer studies solved the problems. The Bureau of Reclamation disagreed. While uncertainties about the reversibility of effects did (and still do) exist, prudent planning reduced the hazards to a minimum. The importance of the program favored a learn-by-doing approach.

The FY67 appropriation of $3.75 million permitted modest expansion of Project Skywater. The major effort continued to be on field projects, with laboratory and other work making significant contributions to the program. Details of the FY 1967 program can be found in Project Skywater 1967 Annual Report, available through the Office of Chief Engineer, Denver, Colorado. The high point of FY67 was the publication of the "Plan to Develop Technology for Increasing Water Yield from Atmospheric Sources," released in November 1966. This report outlines the plans for the future, and calls for the creation of pilot projects during the 1970's. The report also outlines a plan to expand the research program geographically.

The language of the FY68 appropriations permitted, for the first time, the implementation of the planned nationwide program. Heretofore, the Bureau was restricted to programs that benefited the 17 Western States. While research was permitted outside the area, the benefits had to be directed to the 17 Western States. The new provision permitted the letting of contracts for initial studies of projects in the Eastern States. Although Congress appropriated $5 million for FY68, $500,000 was withheld as our share of the savings in domestic programs deemed necessary by the Administration.

Two new activities were initiated during FY68 that have already had a remarkable influence on the course of weather modification research. The first of these is the series of Skywater Conferences begun in July 1967. Each conference considers a single problem associated with precipitation management. An attempt is made to keep the attendance small enough to assure intimate, dynamic, and spontaneous interaction and yet invite as many people as possible who have an interest in the subject. Four Skywater Conferences have been held so far. The first concerned the physics and chemistry of cold cloud nucleation. The second, held in October 1967, considered the design and evaluation of weather modification experiments. In February 1968, the generation and delivery of nucleation materials was discussed. Optimization of operational weather modification was the subject of the May 1968 conference. Skywater V is tentatively set for November 1968 and will consider numerical modeling. Proceedings of these conferences are available.

The second new development is the series of Skywater Cooperative Experiments. These bring together a number of groups with related interests. The cooperating groups gather at one location - thus far the site of a Skywater field project - to intensively investigate specific aspects of an experimental precipitation management program. Co-op 1 was held last winter in the Colorado Park Range. Seeding effectiveness and nuclei diffusion under winter orographic conditions were studied. Co-op 2 considered the same subjects, plus nuclei and water budgets, under summer convective conditions at Flagstaff, Arizona, during August 1968. Co-op 3 is scheduled for the winter of 1968-69 in the Central Sierra Nevada. Co-op 3 is planned to be much longer than the previous co-ops, and will consist of a number of subprograms. Both Co-op 1 and Co-op 2 were marked by a high degree of enthusiasm and cooperation, and each involved both Bureau contractors and non-contractor groups.

Funding for fiscal year 1969 is expected to be at the same level as FY68. A significant feature has been added, however. House Report No. 1788 of the 90th Congress includes a provision for $150,000 to initiate pilot weather modification projects in connection with the atmospheric water resources research program. One of the results of Skywater Conference IV was the identification of the Upper Colorado River Basin as the most reasonable site for the first pilot project. Detailed planning has begun for a program in the San Juan Mountains of Colorado. Instrumentation will begin this fall, with the first seeding set for the 1969-70 winter season. By 1973 we will be getting firm answers on the operational effectiveness of current technology.

Current Activity

To aid us in planning and funding the program we have categorized Project Skywater into 11 activity items. Six of these are grouped together as Research and Development. They are Cloud Physics and Modification Techniques, Cloud Seeding Materials and Equipment, Engineering Design of Modification Systems, Instrumentation and Data Systems, Atmospheric Side Effects, and Special Meteorological Studies. Four others - Hydrologic and Economic Investigations, Legal, Social and Environmental Considerations, Evaluation, and Program Planning - are classified as Planning and Program Definition. The remaining activity - Operational Adaptation - is in a class of its own. It represents the goal of Project Skywater. As the program moves forward, the relative level of effort of these 11 activity items will change. Eventually, of course, Operational Adaptation will command the bulk of the funding.

The Cloud Physics and Modification Techniques activity includes both laboratory and field work. Dr. T. G. Owe Berg is studying the behavior of silver iodide, the University of Denver is looking at ice crystal growth, cloud physicists at the University of Nevada are investigating cloud particle growth, the University of Wyoming is making numerous microphysical measurements within actual clouds, and South Dakota School of Mines and Technology's cloud physicists are studying ice crystal behavior. In the field, Meteorology Research, Inc. is experimenting with summer convective clouds, Texas A&M University is investigating warm cloud processes, while Montana State University, Utah State University, the Universities of Nevada and Wyoming, and the State of Washington, are studying winter storms.

Cloud Seeding Materials and Equipment activity includes the development of a new series of ground and airborne generators by Colorado State University engineers, and the development of generators for organic nuclei by both the University of Denver and Meteorology Research, Inc. Other groups have looked at the nature of the seeding materials themselves.

The Engineering Design of Modification Systems activity integrates the latest techniques and the latest equipment to produce a complete operating system. This activity differs from the first (Cloud Physics and Modification Techniques) in that emphasis is on the system as opposed to the techniques used in the system. Several systems are being tested on both summer and winter storms. E. Bollay Associates, Inc. and the University of Nevada are testing their systems on winter storms, South Dakota School of Mines and Technology is testing a summer convective cloud modification system. Both Fresno State College and New Mexico State University are developing systems for both summer and winter storm modification. North American Weather Consultants is conducting a seeding experiment in Montana's Hungry Horse Basin. This program, because of the Wilderness Area present, cannot install instrumentation in all of the target area. The experiment tests a system using annual streamflow for evaluation.

Instrumentation and Data Systems Development provides the means to gather and process the data used in the various field and laboratory research programs. Telementery systems have been put together by Utah State University, the Universities of Nevada and Wyoming, South Dakota School of Mines and Technology and Meteorology Research, Inc. New York University is developing a laser radar system intended to measure the vertical distribution of water vapor and to aid in distinguishing between liquid water and ice crystal clouds. The Metrology and Calibration System of the U. S. Army Missile Command is being used to calibrate the various electronic equipment used in Project Skywater.

Atmospheric Side Effects are being examined by two contractors. Aerometric Research, Inc. is examining a number of long-term weather modification operations to disclose any alteration of the normal precipitation pattern outside the target areas. So far, the results suggest a precipitation increase downwind of the target under certain meteorological conditions. No widespread or persistent areas of decrease have been found. Montana State University is planning an experiment to evaluate the effects on precipitation up to 100 miles downwind of a target area when orographic clouds are seeded.

Special Meteorological Studies include climatology, terrain effects, nuclei counting, and other supporting research valuable to the program. Colorado State University is

studying the feasibility of using a meteorological wind tunnel to estimate airflow and diffusion for orographic weather modification experiments. Several areas in the Colorado River Basin are being modeled. Meteorologists at UCLA have analyzed data from the Swiss hail experiments to detect those meteorological factors associated with increased and decreased precipitation. ESSA is conducting a number of climatological studies that are helpful in planning experiments.

Hydrologic and Economic Investigations are conducted to aid planning of field research programs and to evaluate the feasibility of large-scale application of weather modification techniques from the standpoint of cost and water supply potential. Colorado State University has developed criteria for identifying specific basins suitable for evaluating weather modification programs. The Travelers Research Center is studying the applicability of weather modification in the Northeast United States, with initial concentration on the Connecticut River Basin. The Pennsylvania State University is developing procedures for predicting hydrologic behavior of watersheds in the northern Appalachian region. The Geological Survey and the Soil Conservation Service are providing supporting services to many of our field contractors by installing stream gages and taking special snow course measurements. The Forest Service is studying the effects of weather modification on watershed performance.

The Legal, Social, and Environmental Considerations research activity attempts to identify and resolve the many problems associated with integrating precipitation management into the social and natural environments. The Universities of Arizona and Wisconsin have looked at the legal complexities, hoping to establish some guidelines. The University of Michigan is analyzing the potential ecological impact of precipitation management. The Forest Service has studied the history of the general plant life of Colorado's Park Range.

The Evaluation activity involves the development of new techniques to evaluate the change in precipitation or runoff following treatment, the analytical review of past experiments, and the development of techniques to measure the amount of seeding material in precipitation. The University of Denver is making independent analyses of some recent cloud seeding experiments. Alternative evaluation techniques that improve validity have been suggested for several programs within Project Skywater. Colorado State University is attempting to develop techniques using runoff to evaluate seeding experiments. Illinois State Water Survey is attempting to define the applicability and limitations of rainfall rate measurements to enable verification and quantitative evaluation of cloud seeding activities on surface rainfall, and is also studying the type and density of sampling required. The University of Nevada has developed techniques to determine the silver content in precipitation samples. The method uses ion exchange and neutron activation.

Program Planning is primarily a duty of the Office of Atmospheric Water Resources. Frequently, however, contractors are asked to make special studies of particular areas to determine the current state-of-the-art and the major gaps. Studies of warm cloud modification and general gaps in weather modification were recently completed.

The final activity, and ultimately the major activity, is Operational Adaptation. Operational Adaptation takes the systems developed under the Engineering Design of Modification Systems activity and tests them under operational conditions, through a series of

pilot projects. Emphasis here is on using the systems and on checking the applicability of a given system in several different areas. Hybrid systems may emerge in the course of the program. Colorado State University, late in FY 1968, began designing the first pilot project. Other pilot projects are under consideration for the Northern Great Plains and other areas.

Concluding Remarks

Project Skywater, with its small beginning just 7 years ago, has grown to a position of leadership in the weather modification field. The enthusiasm and dedication of its contractors, plus the mission-oriented framework of the Bureau of Reclamation and the Department of the Interior are responsible for the remarkable growth and development of the program. The deliberate flexibility of Project Skywater permits changes dictated by our growing knowledge and experience. We have only one preconceived notion - clouds can be modified to increase precipitation. Our goal is to specify the techniques and the systems to affect the modification in the most effective, efficient, and acceptable way, and to make the technology available as a water resources management tool.

WARM FOG MODIFICATION

by
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INTRODUCTION

The clearing of warm fog has important implications for transportation, agriculture, and military operations and so represents a major goal of weather modification. Considerable success has been achieved in clearing supercooled fog (e.g., Vickers and Church, 1966) but such fog is rather rare in the United States. Warm fog, on the other hand, is common, but represents a more difficult problem.

The techniques for warm fog modification presently being investigated are relatively weak by comparison with the more widely known conversion process of water to ice. Materials are required in amounts many times larger than for the supercooled fog case. In addition, possibilities exist for corrosive effects as a result of one of the available methods.

In spite of the weakness of the techniques, the importance of such modification is great and any promising avenues of approach should be pursued. One reason for optimism results from the fact that even small improvements in visibility may be of considerable significance, as in the case of airport traffic. Slight increases in visibility, produced in the approach zone and over the runway, might be sufficient to permit instrument landings without the need for actual clearing.

This paper is intended as a brief review of the present status of warm fog dissipation. Reviews giving much of the background are provided by Stanford Research Institute (Wayne, 1953), AFCRL (Junge 1958), Cornell Aeronautical Laboratory (Kocmond and Jiusto, 1968), and from Russia (Gaivoronskii et al., 1968). This paper is based, in part, on unpublished results of field trials carried out by Meteorology Research, Inc., Cornell Aeronautical Laboratory, and others during the past year. It is the opinion of the author that the techniques are moving through the appropriate laboratory, modeling, and field phases toward an engineering system which satisfactorily applies the proper physical concepts to the solution of various operational problems. It is hoped that the paper reflects this perspective and accurately portrays the present situation.

THE BASIC PROBLEM

There are a wide variety of fog environments, generated by various mechanisms and with differing liquid water contents (LWC), visibilities (V), droplet sizes (diameter, d), concentrations (N), stabilities, turbulence, and wind speeds. Figure 1 illustrates the relationship between liquid water contents, visibilities, concentrations and drop sizes. Typical values for radiation and advection fogs are shown in the figure as given by Jiusto (1964). Radiation fogs tend to have smaller drop sizes, higher drop concentrations and lower visibilities. These differences result from the complex interactions of condensation nuclei number and character as well as the fog formation processes themselves. Much less data are available on environmental stabilities and turbulence in fogs. It would be expected that radiation fogs would exhibit greater temperature

stability than advection fogs, but recent MRI turbulence measurements in a variety of fogs have shown that a very wide range of turbulence values can exist with important implications on the diffusion of seeding material in the fog. The total fog modification problem thus covers a great variety of fog types and the application requirements also range from large-area clearing to small improvements in visibility.

To illustrate the magnitude of the fog modification problem consider a requirement for 700-m visibility in a block 70 m wide, 3000 m long, and 100 m deep to permit airport runway operations. Assume there is negligible wind and turbulence, and the fog has low liquid water content, say, LWC = 0.05 gm/m^3, with 300 droplets/cc, corresponding to a visibility of 300 m (see Fig. 1). For the $2 \cdot 10^7$ m^3 involved, $1 \cdot 10^3$ kg of water must be removed to clear out the fog, or about 750 kg if the need is only to increase the visibility to 700 m. For a moderately severe case with visibility 80 m, LWC can be 0.6 gm/m^3, and twelve times as much water as in the previous case would have to be removed for full clearing. If there is a crosswind of 5 m/sec, a one-hour treatment would increase the air volume to be treated to about $5 \cdot 10^9 m^3$, and $3 \cdot 10^6$ kg of water would have to be removed to wipe out the fog completely, or 95 percent as much if the visibility is to increase only to 700 m.

It is evident from these data that the required water removal can vary by a factor of well over 1000 for the conditions assumed above. In addition, added difficulties may arise from attempts to accomplish this removal in the presence of substantial turbulence and mixing.

METHODS OF FOG CLEARING

Increases in visibility can be accomplished by decreasing the number of natural droplets and/or altering their size. The visibility, V, for a particular fog or cloud can be estimated by use of the equation

$$V = C_1 \left(\frac{d}{LWC} \right) \qquad (1)$$

where C_1 is a dimensional constant, d is the mean droplet diameter in microns, and LWC is the liquid water content in terms of gm/m^3, with V being in meters (see aufm Kampe and Weickmann, 1952, and Best, 1952). C_1 has been estimated by various research workers and found, both empirically and theoretically, in clouds with a broad droplet size distribution to vary considerably with various factors including the definition of d (whether it is mean droplet diameter or the mean volume diameter, e.g., the diameter of the droplet having mean mass) and to decrease by over one-third when very low visibilities are encountered. For the purpose of outlining the main features of warm fog dissipation techniques, we can assume a normal droplet size distribution spread, ignore the decreases in C_1 at low visibilities, and use mean volume diameter. Then, with an error of about $\pm$ 30 percent, one can set $C_1 = 2$, and so

$$V = \frac{2d}{(LWC)} \qquad (2)$$

Figure 1 has been prepared assuming Eq. (2) is valid.

Noting that LWC = $\frac{\pi}{6} N d^3$, where N is the number/cm^3, and that the total droplet surface area $A = N \pi d^2$ (assuming, for simplicity, that the mean volume diameter is the

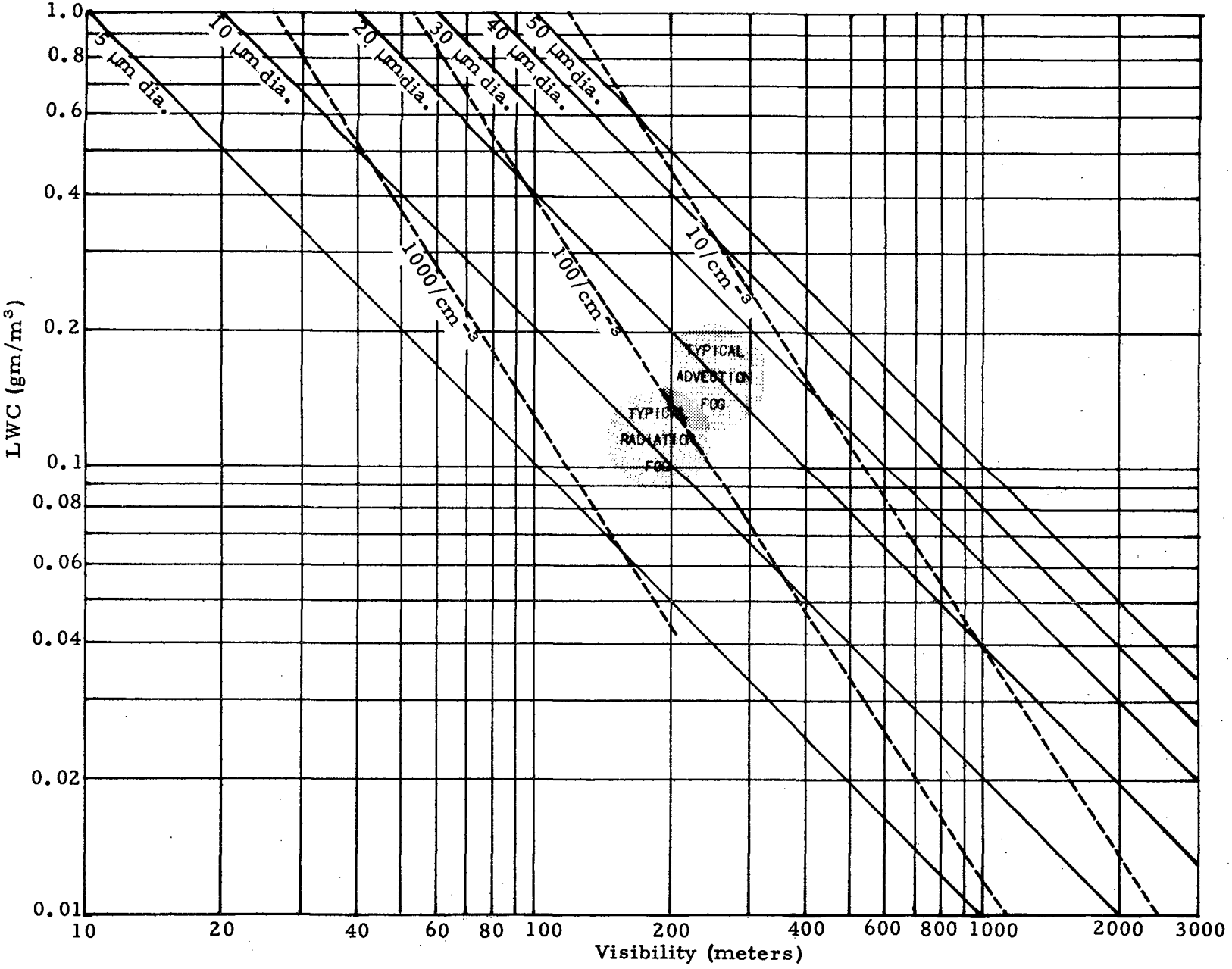

Fig. 1. APPROXIMATE RELATIONSHIPS FOR FOG WATER, VISIBILITY, CONCENTRATION

same as the mean surface area diameter, then $V \sim A^{-1}$. To increase V thus involves a decrease in the total surface area of the droplets. This can be done by three basic methods: (1) arranging the liquid water into the form of fewer, larger droplets (a weak method), (2) removing liquid water by precipitating it out, and (3) removing liquid water by evaporating it. One technique may involve all three methods. For example, introduction of hygroscopic particles first causes condensation growth on the particles and evaporation of the smaller natural droplets, leading to the fallout of the large particles. For large numbers of hygroscopic particles, the relative humidity may even be less than 100 percent, and so more fog may evaporate as the dried air mixes into adjacent areas.

The effect on visibility of altering d, LWC, or N can be derived from Eq. (2) with the results also being evident on Fig. 1.

a. If LWC is held constant, $V \sim d$

$V \sim N^{-/3}$

b. If N is held constant, $V \sim d^{-2}$

$V \sim LWC^{-2/3}$

c. If d is held constant, $V \sim N^{-1}$

$V \sim LWC^{-1}$

THE AIRCRAFT WAKE METHOD

Immediately behind an aircraft of span "b" the aircraft wake assumes a semi-stable configuration of a descending oval cylinder of width 1.62b and depth of 1.33b, containing two parallel vortices distance 0.79b apart. The wake, with its enclosed circulation, descends at a rate in the range of 1 m/sec to 3 m/sec, depending on (weight) x (speed) $^{-1}$ x b^{-2}. If the aircraft is flying in dry air barely over the top of a fog, the dry wake will descend into the fog and evaporate droplets, locally improving visibility. The wake thus serves as a potential technique for fog modification but also serves to complicate experimental results obtained through other techniques. How far the wake descends before mixing with the fog, and how rapidly the mixing occurs are complex functions of the wake characteristics, the turbulence and stability of the environment. Descent to depths of 20 to 80 m below the aircraft are common with medium and large aircraft. A helicopter in normal forward flight has a wake comparable to a fixed wing aircraft; in hovering flight, however, the vertical momentum can be concentrated into one small area and a far deeper vertical descent of the air can be established.

The drying effect can be quite large when the wake is large and when the air in which it originates is rather dry. There is no cost of dispensed material and no problem of precipitating corrosive or toxic materials on the ground. Unfortunately, the method requires a limited

range of environment conditions. Air above the fog must be rather dry, and the fog depth and stability must be such that the dryness can be mixed into the desired region. The stable layer near the top of a typical fog greatly limits the depth to which the wake can descend. Helicopter tests were carried out by MRI using a Sikorsky S-55, weighing 8400 lbs. and having a 52-foot diameter rotor. The hovering technique in thick fog did not prove to be useful; presumably effects were confined to such a narrow chimney in the fog that they were not visible. However, at a slow cruise, the effects were quite distinct, with clearing down to about 50 to 60 m. Where the fog was thin, this amount of clearing would completely cut through the fog, and sizeable clearings could be created in a few minutes.

Air Force experiments have been conducted with a giant helicopter of about 40,000 lbs., gross weight. Because of the large size, weight, and power of the vehicle in hovering, appreciable wake effects can be felt even 1000 ft. below. The Air Force trials have demonstrated considerable success in fogs to 300 ft. deep, and it is reported that the technique has been used for conducting rescue missions in actual military operations.

THE HYGROSCOPIC MATERIAL METHOD

This method involves the dispensing of drying agents into the fog to cause evaporation of the fog particles. The size of the hygroscopic particles is carefully chosen so that they will collect water rapidly and efficiently and yet fall completely out within a reasonable time. Very small particles may not fall out and can actually stabilize the cloud. The optimum size range depends on the fog conditions and the dispensing technique. Many materials are available for this role--salts, fertilizers, and acids--with the choice depending on relative efficiency, cost, ease of sizing and dispensing, and toxicity and corrosiveness.

The water removed from the fog is typically only about 10 to 50 times greater than the original mass of the hygroscopic material although, given long time intervals, the efficiency can be greatly improved. The method is relatively simple and lends itself well to mathematical modeling and optimum engineering but, nevertheless, even with such optimizing, large quantities are required for opening an airport.

The efficiency, in terms of water condensed per unit mass of material at equilibrium at high relative humidities, is proportional to the number of ions dissociated per molecule divided by the molecular weight. Common sodium chloride turns out to be one of the most efficient materials, with only the more expensive and corrosive lithium chloride and ammonium chloride being more efficient. Other commonly tried materials are urea and calcium chloride. Materials which have low deliquescence points, such as lithium chloride and calcium chloride, are somewhat difficult to dispense because of clogging of the disseminators, even with fluidizing agents employed.

Rather complete numerical models of fog dissipation have been prepared by several groups, primarily modeling aircraft dissemination. They show that a relatively large amount of material is needed for typical 100-m and deeper fogs without turbulence, and that turbulence increases the needed amounts considerably. For a typical salt particle size distribution of 20 to 40-micron diameter, about 245 kg of material would be required to remove the water from a volume represented by a width of 65 m, depth of 100 m, and length of 1500 m under conditions of no turbulence. A number of MRI tests have indicated that amounts of 10 or 100 times this value might be required under some atmospheric conditions where turbulence dilutes the effects and the treatment is spread over a larger volume. Successful tests by Cornell Aeronautical Laboratory, as reported in Aviation Week, involved 220 kg of material

dispensed in a series of passes under relatively light turbulence conditions.

The hygroscopic material method obviously shows promise. For routine clearing of airports to permit terminal operations, careful engineering of the system permits handling the simple cases. There remains a question of how far one can go in handling the deeper, windier, and more turbulent cases. Corrosion can represent a major problem from the repeated, localized releases of large amounts of the commonly used materials, but use of other materials can minimize this problem.

OTHER APPROACHES

The reviews cited in the Introduction describe many possibilities for warm fog dissipation. The work of Jiusto and Pilie', in particular, checked quantitative aspects of many of these alternatives and concluded the most promising method was the straightforward hygroscopic approach. In a complete systems study, one should also look beyond merely dissipating fog. If one can improve the methods of coping with it, this is also of value; better forecasting its onset and natural dissipation; planning to locate facilities in fog-free areas; monitoring visibility with remote, telemetry devices and with remote indirect probing devices; improving blind landing aids; utilizing better lighting for seeing through fog with eyes or with IR equipment; etc.

Other Methods of Condensation or Coalescence

If the particles released into the fog could collect more water per gram than the standard hygroscopic material, greater efficiency would result. Two possibilities, surfactants and polyelectrolytes, have received attention recently, but the attention has not been accompanied by presentation of detailed, quantitative description of the possible mechanics of the processes involved. Since the methods therefore cannot be put into numerical models, and since field observations without a numerical modeling framework are easily misinterpreted unless they are very carefully done with extensive instrumentation and statistical controls, it will be difficult for such techniques to gain acceptance unless they work with spectacular efficiency. Surfactants are deemed to facilitate droplet growth by decreasing surface tension, but theoretically the effect will be negligibly small for fog size droplets. Polyelectrolytes are apparently considered to cause electrical charges and gradients and thereby increase the coalescence between droplets. Again, theoretical calculations do not support the hypothesis quantitatively.

Coalescence from Spray

Todd (1967) calculated the sweepout effect of water spray and concluded that if water droplets in the 50-micron diameter range could be sprayed into fog, visibility would be improved with not unreasonable amounts of water. This subject was recently examined in depth by Buxton, Chechile, and Davis (1968). The general conclusion was that, considering the droplet creation problem and practical realities of size distributions and fan wake characteristics, the technique offered rather limited possibilities.

Carbon Black

If carbon black is dispersed into the top of a cloud onto which the sun is shining, more of the radiant solar energy will be absorbed in the cloud and the cloud will become warmer and the water droplets will tend to evaporate. There is considerable background on using carbon

black in weather modification experiments (see the review of Downie, 1960, and calculations by Fenn and Oser, 1962). The main field experiments were conducted with complex, convective clouds, before the days of numerical modeling, and with inconclusive results. Used in fog (Ettenheim, 1962) at Arcata, California, results were somewhat encouraging. The major disadvantage is that the technique requires sunlight.

Direct Heating

The well-known FIDO approach dates from its use in England in WW II. Fuel is burned in huge quantities around the edges of a runway. Trials in the United States were not promising, although there were operational uses in England. If the burners are not carefully spaced, they induce local convection in which the dried, cleared air rises and is replaced by fog near the surface. The huge open flames are inappropriate for civilian airport operation and the cost proves rather prohibitive. In France, at Orly Airport, intriguing experiments have been conducted with a network of burned jet engines. Clearing was satisfactory, but noise and economics proved to be stumbling blocks.

Miscellaneous Techniques

For limited areas, trees (especially pine trees, whose narrow needles offer good collection efficiency) will sweep out considerable water from a fog. Series of wires or screens will do likewise. For some locations, it is simple and convenient to plant trees appropriately. The method is especially promising for crosswind highways, where a narrow effect is all that is required. The subject has been investigated in Japan as well as in the United States.

One can also seek to keep the fog from being generated in the first place. In Russia, Bakhanova and Solyanek (1968) had success using evaporation suppressants on a lake surface when cold air (say, -15C) blew over the warmer (0°C) lake. The shallow natural fog was locally cleared, with the use of reasonably small amounts of material.

Air pollution can contribute significantly to the stability of a fog, by providing artificial condensation nuclei which are large enough to have droplets form on them but small enough so the droplets do not fall out rapidly. Eliminating the pollution can serve to decrease the amount and stability of natural fog, and increase the likelihood of success of using fog dissipation techniques.

CONCLUSIONS

Several methods have shown promise for warm fog dissipation. The methods are well understood and are capable of being engineered to good efficiency. Potentially useful results are obtained for the simplest cases of shallow fog with little wind or turbulence, especially those cases when the natural weakening process is in operation in the morning. None of the methods appear capable of handling the severest situations of dense, deep fog in a moving or generating phase. Future exploratory work should be performed in a careful, quantitative manner, with the goal of extending, as far as possible, the use of each technique toward the more difficult tasks.

ACKNOWLEDGEMENTS

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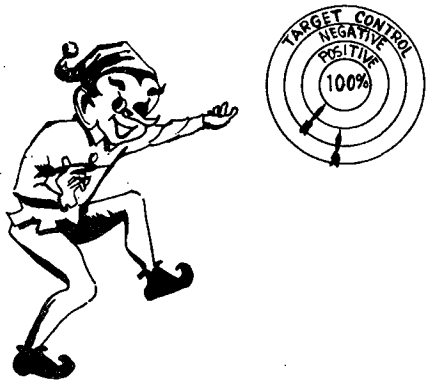

THE DEPENDENCE OF PRECIPITATION RATES UPON THE TIME POSITION WITHIN STORMS

George W. Reynolds *

From the viewpoint of statistical evaluation of precipitation production by cloud seeding, there is no statistically feasible, dynamically uniform experimental time unit. Storms vary in duration and intensity, meteorological and orographic influences vary within a storm, days with precipitation include different numbers of precipitating hours from storms of different intensities, etc. It therefore seems desirable to go to the shortest period compatible with measurement capability in order to approach internal physical homogeneity within a single member of a sample. Without this homogeneity, the selection of realistically comparable seeded and unseeded events becomes more difficult, and more events are required for reliably establishing conclusive statistical significance levels.

If an experimental time unit which is shorter than the durations of the storms under investigation is selected, possible systematic effects of the time position of each test period within its storm must be considered. If the time unit is for a fixed number of hours of storm, it can be expected that the generators will not always be turned on at the beginning of each storm or even at the same number of hours after the beginning of precipitation. Certainly, if one uses a 24-hour day (Grant. et al.), [1] the precipitation amounts under test will not always be from the same time position within storms. That is, sometimes one may be considering only the first hours of precipitation, at other times only the last few hours of storm, etc.

This is a report of an investigation of possible systematic variability in precipitation rates as storms progress, in time, at each of 3 selected stations. A study of possible systematic diurnal influences will be reported later.

The Data

The basic data were taken from the ESSA publication, "Hourly Precipitation Data," [2] for the period from November 1956 - April 1966. The study was applied only to the "winter" season, November through April. The three stations under investigation are Silver Lake Brighton, Logan (USU), and Echo Dam (Figure 1).

Silver Lake Brighton (8,700') is a high altitude, relatively high precipitation yield station, near the top of the western side of the Wasatch Mountains. Logan (USU) (4,800') is in the

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*Wasatch Weather Modification Project, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321. This study was accomplished under Bureau of Reclamation Contract No. 14-06-D-6003, dated 1 July 1966, as amended.

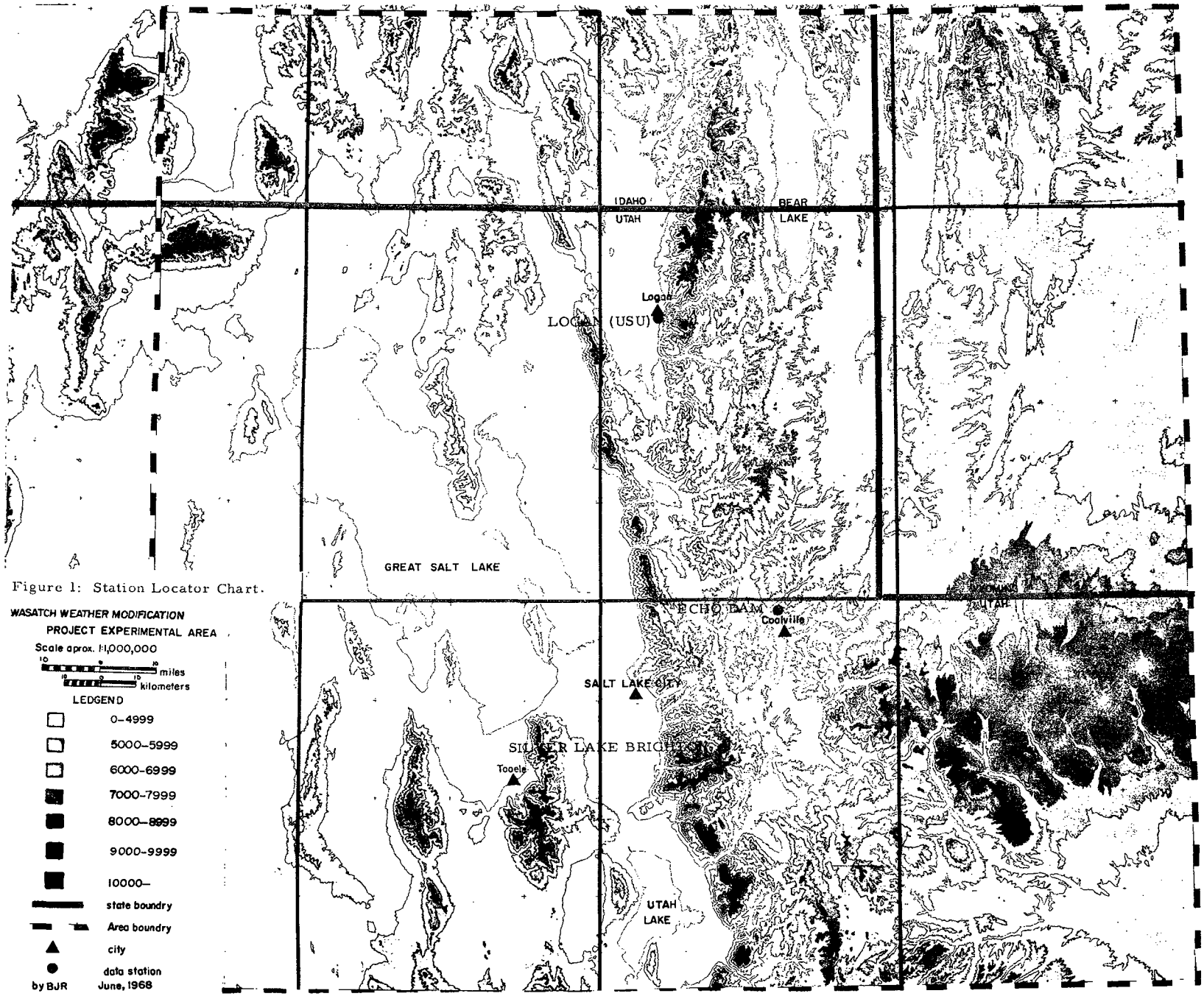

Figure 1: Station Locator Chart.

Cache Valley, which is immediately to the east of the leading (western) edge of these mountains. The precipitation yield is moderately high for a low altitude station, probably because of the Wellsville Range immediately to the west. Echo Dam (5,500') is about 25 miles to the east of the Wasatch Front. Considerably less winter precipitation is reported for Echo Dam than is reported for Logan (USU).

From the viewpoint of possible penetration effects, it would obviously be desirable to summarize the data for a high altitude station which is well within the mountains. Apparently, there is no such station for which hourly ESSA data are available. It may be possible to obtain appropriate Forest Service data at some later date.

The Method

For each station, separate summaries were prepared for 1, 2, 3, and 6 hourly periods, for each month from November through April. The appropriate precipitation rates during the first 12 hours of "12-hour storms" were investigated. "12-hour storms" were defined as storms which lasted for 12 hours or longer. A storm was defined as a precipitation period during which: there were no sub-periods of more than 3 continuous hours during which at least .01" was not reported; precipitation was reported for at least one-half of the hours.

The arithmetic mean for each period was computed separately for each month. For example, the means for all November "12-hour storms" from 1956-1965, for Silver Lake Brighton, were computed each for the 1st hour, the 2nd hour, the 3rd hour, etc. These means were then graphed to provide indications of possible systematic trends.

The "Friedman Two-Way Analysis of Variance by Ranks" test was applied to the data for each station-month-length of period group. This nonparametric test for "the case of k related samples" is adequately described by Siegel. (3) The null hypothesis is "that the k samples have been drawn from the same population," and at least an ordinal scale is required.

Separately for each storm, a rank is assigned to each member of a group according to the amount of precipitation recorded for the appropriate period of measurement. The question is whether these ranks are systematically repeated from storm to storm. The Friedman test provides a quantitative estimate of how often at least the observed amount of repetition would occur, if all of the samples within a test were from the same population.

To provide maximum information, the storms should be stratified according to meteorological circumstances, using the same criteria that will be applied to cloud seeding evaluation. However, such a procedure would not have provided enough storms for reliable testing. The interpreter must remain aware of the possibility of the dilution of the results by this lack of stratification.

Results

Table 1 indicates the portion of samples that would exhibit at least the observed repetion in ranking, if the amount of precipitation received were not dependent upon the position of the period within the first 12 hours of storm. For most of these groups, the value of the significance level is well above .05, which is a fairly liberal rejection level. Therefore,

Station: Silver Lake Brighton
November 1956 to April 1966

	N	Hourly Rates	2 Hour Rates	3 Hour Rates	6 Hour Rates
NOVEMBER	21	.90-.95	.80-.90	.50-.70	.10-.20
DECEMBER	32	.70-.80	.30-.50	.70-.80	.50-.70
JANUARY	38	.30-.50	.20-.30	.30-.50	.50-.70
FEBRUARY	38	.02-.05	.02-.05	.02-.05	.80-.90
MARCH	43	.02-.05	.20-.30	.30-.50	.50-.70
APRIL	42	.90-.95	.50-.70	.50-.70	1.00

Station: Echo Dam
November 1956 to April 1966

	N	Hourly Rates	2 Hour Rates	3 Hour Rates	6 Hour Rates
NOVEMBER	3	.30-.50	.50-.70	.10-.20	1.00
DECEMBER	7	.20-.30	.20-.30	.10-.20	.70-.80
JANUARY	7	.30-.50	.20-.30	.30-.50	.10-.20
FEBRUARY	8	.50-.70	.50-.70	.30-.50	.70-.80
MARCH	9	.20-.30	.10-.20	.20-.30	.50-.70
APRIL	9	.02-.05	.05-.10	.01-.02	.10-.20

Station: Logan (USU)
November 1956 to April 1966

	N	Hourly Rates	2 Hour Rates	3 Hour Rates	6 Hour Rates
NOVEMBER	8	.80-.90	.80-.90	.80-.90	1.00
DECEMBER	12	.10-.20	.80-.90	.50-.70	.30-.50
JANUARY	11	.30-.50	.10-.20	.10-.20	.20-.30
FEBRUARY	9	.50-.70	.70-.80	.50-.70	.70-.80
MARCH	11	.50-.70	.50-.70	.10-.20	.30-.50
APRIL	10	.30-.50	.30-.50	.30-.50	.20-.30

Table 1. The significance levels for each station-month-length of period group as estimated by the Friedman test. (N indicates the number of storms for each group. The significance level is between the indicated values. Further precision is neither necessary nor justified.)

the statistical tests do not justify a conclusion that, in general, precipitation rates do depend upon the time position within storms.

The significance levels for only six of the 72 tests are between .01 and .05 with none less than .01. The occurrence of this many within the .01 - .05 bracket, with precipitation rates completely independent of the time position within storms, would not be surprising. It must, of course, be recognized that test results for 2 hour rates are not independent of the results for hourly rates, etc. It seems especially interesting to note that none of the 18 significance levels for 6 hour rates was in the .01-.05 bracket.

Although the Friedman test results do not justify concluding that there are systematic trends in precipitation rates during "12-hour storms," they do not eliminate the possibility that such trends do in fact exist. It seems possible that there may actually be such dependence for storm systems which include the more intense periods of precipitation. Insofar as a rank test is concerned, such a systematic trend could be hidden by the inclusion of a sufficient number of less intense precipitation periods, during which the variations in precipitation amounts were somewhat random. In fact, for lower precipitation rates an apparent randomness could result from inadequate resolution in the measurement system, even though the actual precipitation rates were systematically distributed.

It therefore seems worthwhile to examine and interpret monthly graphs of mean precipitation rates against the number of hours after the beginning of storms. Figures 2 and 3 represent trends for groups with moderately low values for the significance levels. It appears that, in February, Silver Lake Brighton precipitation tends to peak at about six hours after the beginning of a storm. A possible explanation may be that this weather is associated with a transient trough or low. (4) On the other hand, April storms at Echo Dam seem to start with high rates and gradually swindle.

Figure 4 is an example of a strong graphic indication of a systematic decrease in precipitation amounts, without supporting significance levels from the statistical tests. For four of the months for Logan (USU), three of the months for Echo Dam, and two of the months for Silver Lake Brighton, one might have interpreted the graphs to indicate systematic behavior, but without support from the Friedman test. However, in only 3 or 4 cases is the indication so marked as to justify doubt as to the adequacy of the statistical technique, as applied.

Figure 5 is an example of agreement between the apparent lack of a systematic trend in the means and the results of the statistical tests.

The question arises as to whether differences in precipitation yields as storms progress are large enough to be of practical significance, without regard to statistical significance. Since Table 2 reveals differences within station-month-length of period groups of as much as .06", .08", .11" and .15" for 1, 2, 3, and 6 hour means respectively, it seems obvious that the apparent magnitudes of variations within all of these periods is of practical significance. Therefore, the concern over statistical significance is justified.

One notices from Table 2 that the maxima for Logan are often greater than for Silver Lake Brighton. In some instances this is also true for Echo Dam. This apparent disparity is emphasized in Table 3, which gives comparative figures for Logan and Silver Lake Brighton for November.

1 Hour Means

	Logan (USU)		Echo Dam		Silver Lake Brighton	
	Min	Max	Min	Max	Min	Max
Nov.	.01	.06	.003	.04	.03	.05
Dec.	.01	.07	.02	.07	.02	.03
Jan.	.01	.04	.01	.03	.02	.03
Feb.	.01	.04	.01	.03	.02	.05
Mar.	.01	.04	.01	.04	.02	.05
Apr.	.02	.06	.01	.07	.02	.04

2 Hour Means

	Logan (USU)		Echo Dam		Silver Lake Brighton	
	Min	Max	Min	Max	Min	Max
Nov.	.04	.10	.02	.05	.06	.08
Dec.	.04	.10	.05	.12	.04	.06
Jan.	.03	.07	.01	.04	.04	.06
Feb.	.03	.07	.01	.04	.04	.09
Mar.	.04	.07	.02	.07	.06	.08
Apr.	.04	.10	.03	.11	.05	.07

3 Hour Means

	Logan (USU)		Echo Dam		Silver Lake Brighton	
	Min	Max	Min	Max	Min	Max
Nov.	.07	.16	.03	.09	.09	.13
Dec.	.06	.14	.07	.15	.07	.09
Jan.	.05	.09	.03	.05	.07	.09
Feb.	.04	.09	.02	.05	.08	.12
Mar.	.05	.10	.05	.08	.09	.11
Apr.	.08	.15	.05	.16	.08	.11

6 Hour Means

	Logan (USU)		Echo Dam		Silver Lake Brighton	
	Min	Max	Min	Max	Min	Max
Nov.	.18	.29	.10	.12	.18	.22
Dec.	.16	.24	.22	.24	.14	.16
Jan.	.11	.18	.06	.08	.15	.16
Feb.	.11	.18	.07	.09	.21	.21
Mar.	.13	.17	.13	.15	.20	.21
Apr.	.20	.24	.11	.26	.18	.19

Table 2. Minimum and maximum mean precipitation rates (hundredths of an inch/period). Underlined values emphasize the months with the greatest differences for each station, for each length of period.

	N	1	2	3	4	5	6	7	8	9	10	11	12
1 Hour Means: Logan (USU)	8	.05	.06	.06	.04	.06	.03	.03	.04	.03	.03	.02	.01
Silver Lake Brighton	21	.03	.03	.04	.03	.03	.03	.03	.03	.03	.05	.04	.04
2 Hour Means: Logan (USU)	8		.10		.10		.09		.08		.07		.04
Silver Lake Brighton	21		.06		.06		.06		.06		.08		.08
3 Hour Means: Logan (USU)	8			.16			.13			.11			.07
Silver Lake Brighton	21			.09			.09			.09			.13
6 Hour Means: Logan (USU)	8						.29						.18
Silver Lake Brighton	21						.18						.22

Table 3. Mean precipitation rates, (hundredths of an inch/period), Logan (USU) and Silver Lake Brighton, November, 1956 - 1965.

Although the mean precipitation rates at Logan (USU) are greater than for Silver Lake Brighton, the ratio of the number of storms is only 8/21 and the mean November precipitation is 3.8" (Logan (USU) and 8.4" (Silver Lake Brighton) respectively. This combination of factors suggests that Silver Lake Brighton has many so-called "12-hour storms" which are essentially weak-yielding, orographic in character, whereas for Logan (USU), in general, periods of extended precipitation are associated with more general, higher yield storm systems. The fact that the Silver Lake Brighton graphs show fewer and less pronounced apparent systematic trends within storms supports this possibility. It could be that limiting the Silver Lake Brighton samples to those storms which are concurrent with the Logan (USU) precipitation periods might produce a significantly different time pattern.

In any event, this marked difference in precipitation rates and frequencies of storms suggests the desirability of using whether or not there is an extended period of natural precipitation at a low altitude station, near the Wasatch Front (such as Logan, USU), as a stratification criterion.

Conclusions

The magnitudes of the variations in 1, 2, 3, and 6-hour precipitation rates with "12-hour" storms are large enough to be of practical significance. For only a few station-month-length of period groups, can the null hypothesis that there is no dependence of precipitation rates on the time-disposition within storms be rejected at the 5% level, using the Friedman non-parametric ranks test.

Therefore, one must conclude that the results of these tests do not justify the conclusion that there is a systematic trend in precipitation rates during "12-hour storms." Graphs of the trends of mean precipitation rates suggest that in some instances this particular statistical test may not be sufficiently sensitive for the statistical recognition of systematic precipitation trends within storms. It also seems possible that stratifying according to whether the precipitation is from a storm system or is entirely orographically induced might increase the number of rejections of the null hypothesis at the .05 level, especially for the storm system class.

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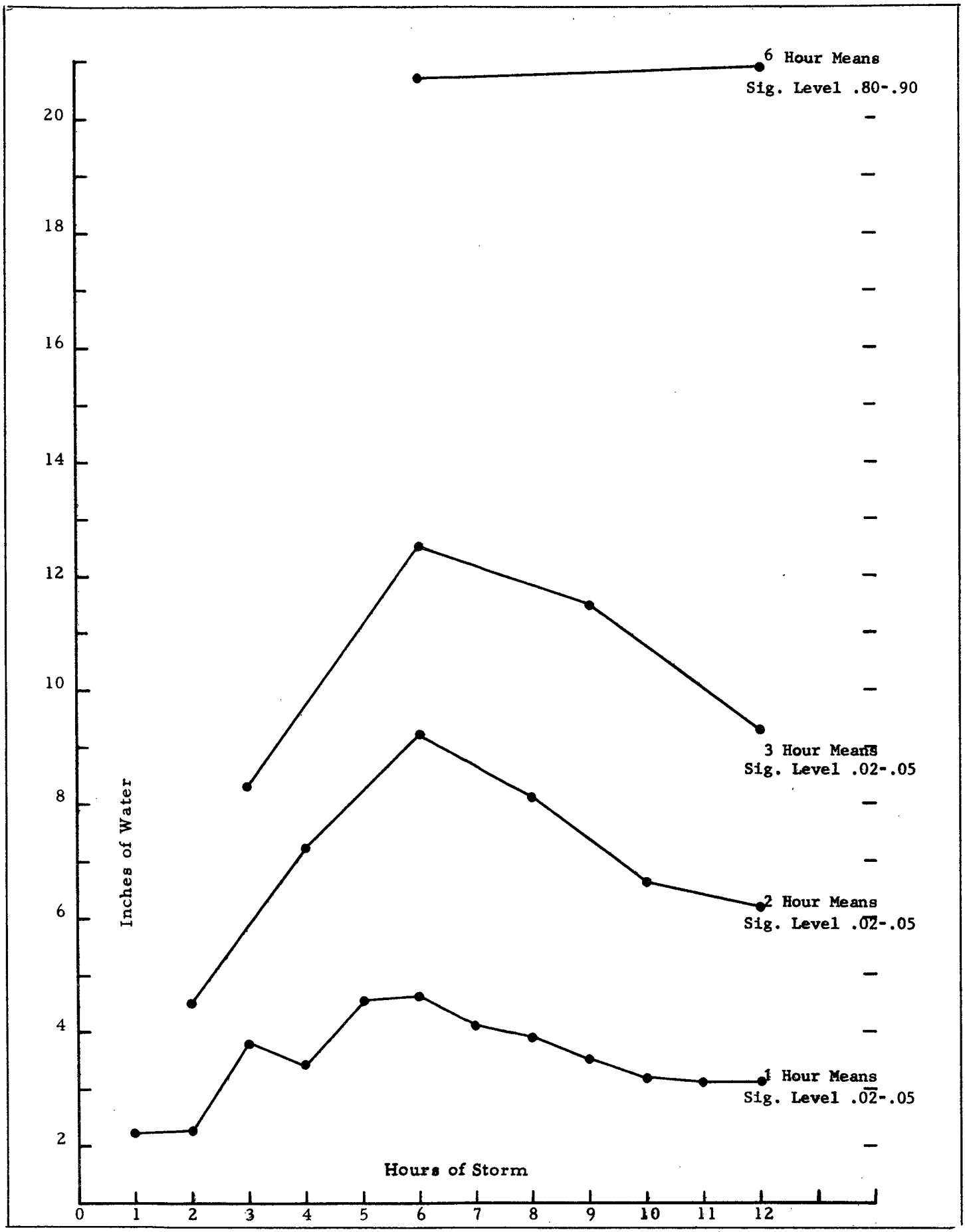

Figure 5. Mean precipitation for indicated periods, plotted according to the time position within 12 hour storms. Silver Lake Brighton. February.

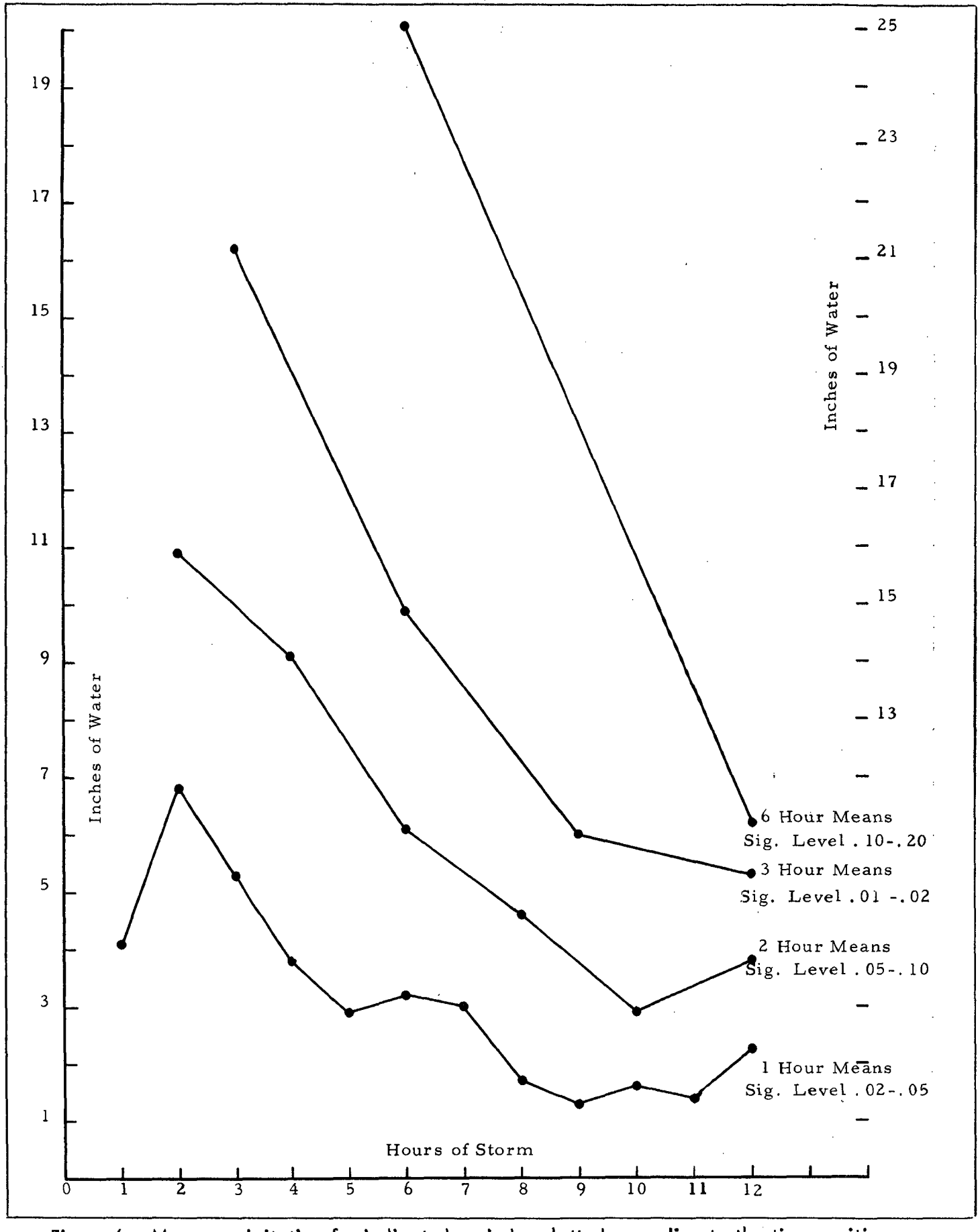

Figure 6. Mean precipitation for indicated periods, plotted according to the time position within 12 hour storms. Echo Dam. April.
(Scale on the right applies to the 6 hour means.)

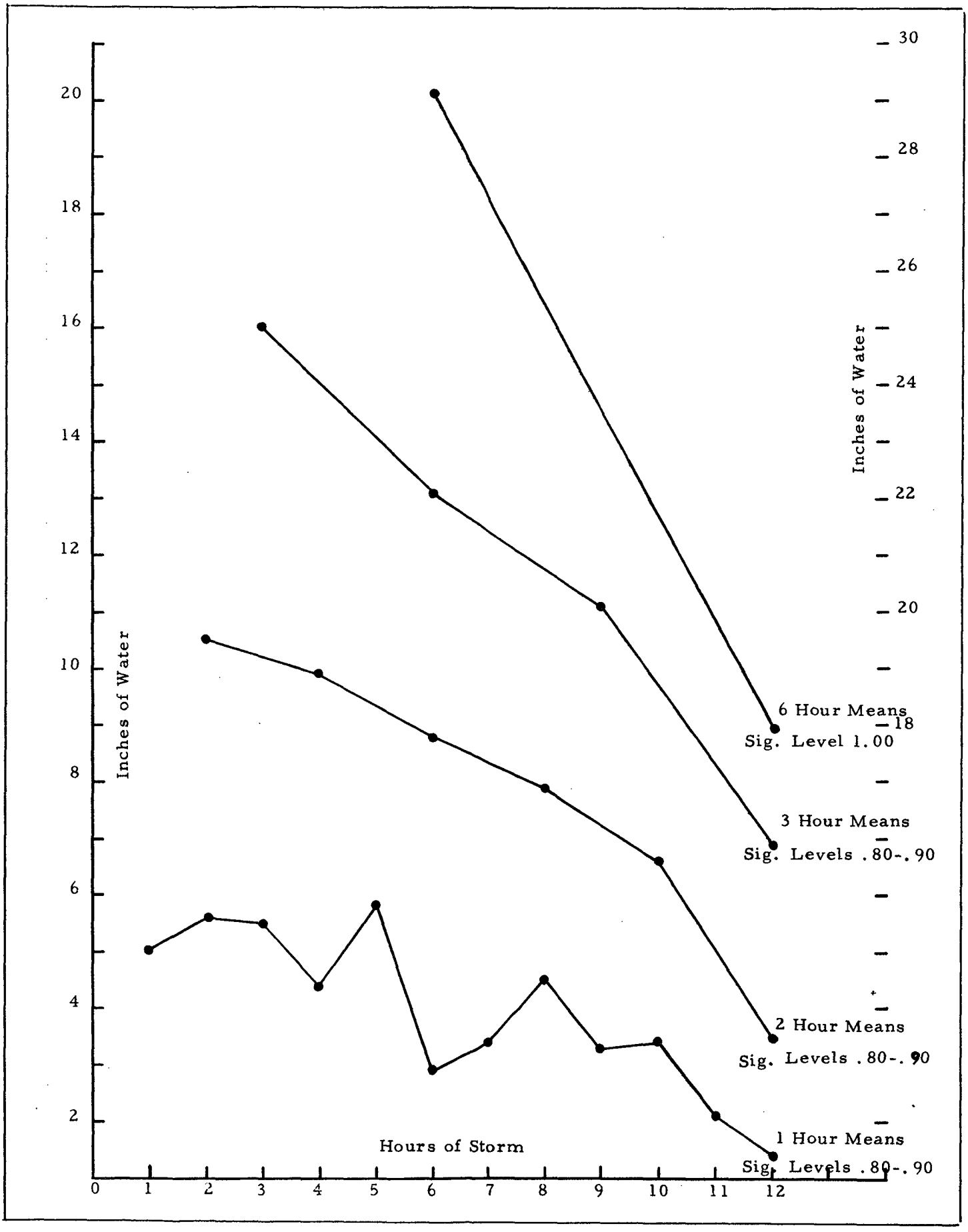

Figure 7. Mean precipitation for indicated periods, plotted according to the time position within 12 hour storms. Logan (USU). November.
(Scale on the right applies to the 6 hour means).

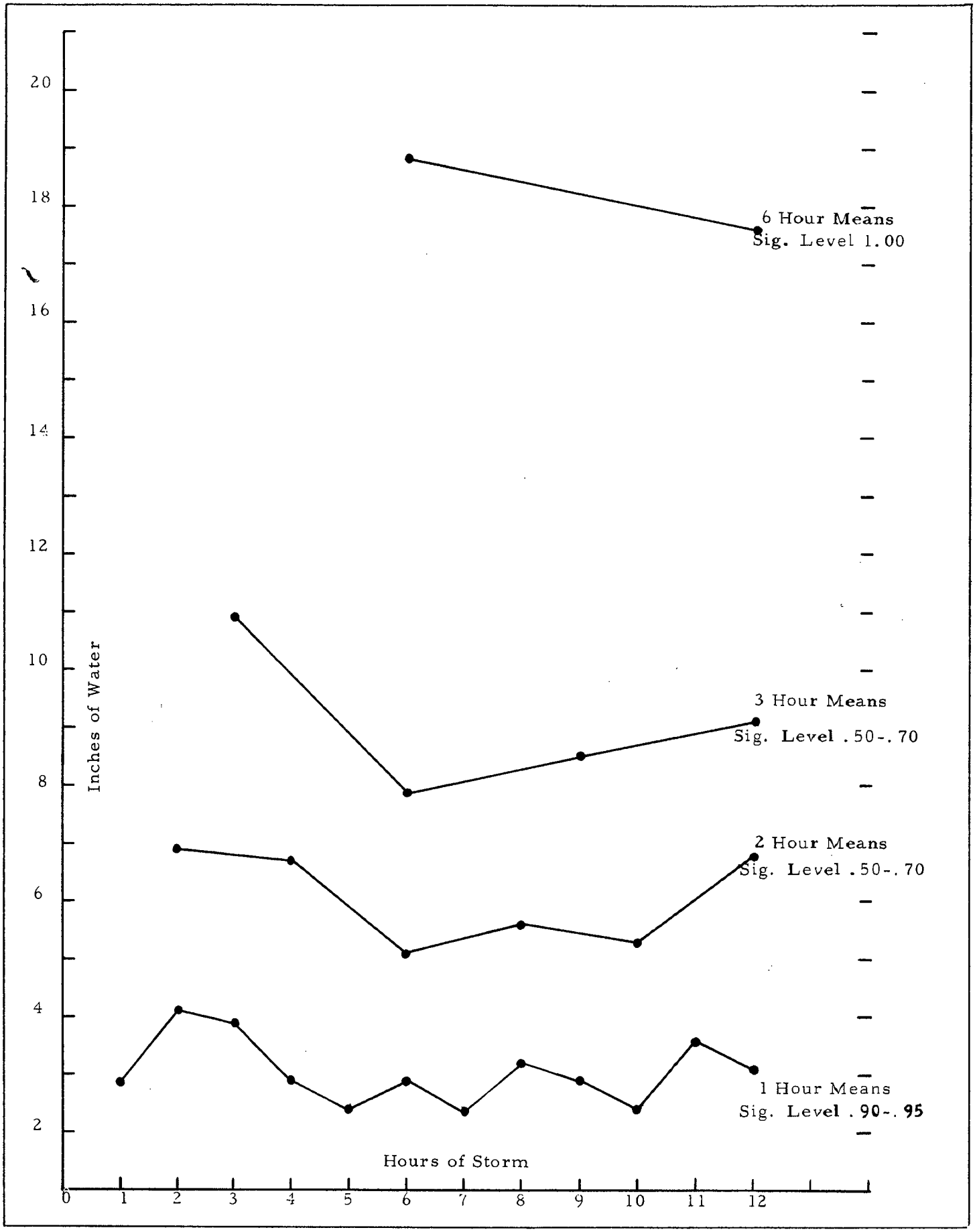

Figure 8. Mean precipitation for indicated periods, plotted according to the time position within 12 hour storms. Silver Lake Brighton. April.

AN OPERATIONAL HAIL SUPPRESSION PROGRAM IN KENYA

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The Kericho area of Kenya, East Africa, is considered to have the highest hail incidence of any location in the world. Thunderstorms often occur over the area on more than 200 days per year. There is evidence that hail is present during some portion of these storms in at least 85% of the total cases. The average diameter of these hailstones is in the range of 5-15 millimeters, but occasionally a few hailstones have been found which have diameters up to 45 millimeters. Hail has been recorded in every month of the year but the most severe damage appears to occur during the February--March and August--September periods. Single high intensity storms can occur at any time.

Little is known about the total distribution of hail from any single thunderstorm which moves across the Kericho area. An assessment of damage to tea has provided modest information about the hail distribution as it occurred over those areas where estates are in production. Practically nothing is known about the distribution of hail from the storms which develop over the forest, pass over the tea areas, and move onward over the relatively unpopulated sections.

In the Kericho area there are some 30,000 acres of tea in production. Within this area hail produces an average annual crop loss of more than 1,500,000 pounds of "made tea." This term applies to the final product as it comes from the factory ready for shipment as opposed to "green leaf," which is the term applied to the freshly picked leaf before it enters the factory. The average loss from each hailstorm on a single estate is approximately 9,000 pounds of "made tea," but some storms have produced more than 100,000 pounds loss on one estate. The total area has a point frequency of about 10 hail instances per year.

On 1 October 1967, Atmospherics Incorporated initiated a hail suppression program in the Kericho area. The general design of this program involves the aerial application of silver iodide nuclei in the inflow area thought to be important to that particular cloud volume which gives birth to the hailstones. Attempts have been made to apply the material at rates sufficient to produce freezing nuclei concentrations of 10^5 per cubic meter effective at -15^C within this hail producing volume. Pyrotechnic generated silver iodide has been used exclusively for this purpose.

During the first 14 months, AI has provided one turbocharged Twin Comanche aircraft for delivery of seeding materials and one ATMOS IV Radar System, installed atop a small building near the Tea Research Institute. The project was designed and is currently operated by AI personnel on the site. These people include one radar meterologist and one pilot.

On 1 January 1969, a second aircraft was added to the project and three AI personnel remain fulltime in the area. The second phase of this operational program will continue through September, 1970.

The mechanisms which produce hail and the areas where hailstones develop appear to be similar to those found in the "Hail Alley" of the United States. Inflow areas surrounding the hail-bearing cells in the Kericho area are found on both the leading and trailing edges of storms depending upon the particular type weather situation. There seems to be a seasonal variation in the type most frequently noted during any particular time period but the fundamental physical characteristics are straightforward.

Evaluation procedures are based on an assessment of hail damage in terms of loss of "made tea." At the conclusion of each hail instance, the tea estate managers (one manager for every thousand acres) assess the loss by estimating the amount of leaf available for plucking in comparison with the average yield on the three previous plucking rounds. The experienced estate managers are more or less standardized in their assessment procedures. In addition, the managers make a reassessment of damage based on the actual amount of "made tea" received from the area where the initial assessment was conducted. This is accomplished after the particular crop has been processed through the factory. Inasmuch as the crop is normally plucked each ten-fifteen days and the growing conditions are reasonably stable, this method of assessment does provide a significant indication of loss resulting from hail.

Fortunately, the hail usually falls from individual cumulus developments which move across the area as single units. Often a choice of which cell to seed is necessary during any particular mission and the one which appears the most severe is usually picked for treatment. This may allow some bias to creep into any comparisons of seeded and unseeded storms but the bias would more than likely be against any indication of hail damage reduction. In any case, many of the individual cumulus cells are necessarily left unseeded. Much of the time there is no physical connection between these individual cells and often they are so far removed from each other, it is unlikely any dynamic interation exists.

During the first 16 months of operation, more than 300 operational days and 325 seeding flights have been logged. The amount of damage to tea resulting from nearly 500 hail instances has been supplied by the various tea interests on standard reporting forms. An examination of these data based on seeded and unseeded hail producing cumulus cells indicates the following average loss in "made tea" per hail instance:

Seeded -- 2850 pounds per hail instance

Unseeded -- 7260 pounds per hail instance

The above figures indicate a reduction in hail damage of about 60%. It should be emphasized, this analysis does not include all those storms which were seeded and produced no hail instances. Approximately 720 individual precipitation cells have been seeded and only 65 hail instances have been recorded from these particular cells. A total of 385 hail instances have been recorded from an unknown number of additional precipitation cells which were not seeded.

A more rigorous statistical analysis is planned for all data as additional information becomes available.

PROFESSIONAL STANDARDS IN WEATHER MODIFICATION

Merlin C. Williams *

I INTRODUCTION:

It is becoming increasingly evident that any single weather modification treatment technique is not likely to produce a desired beneficial result under all circumstances. On the contrary, natural variation in weather systems may cause a particular treatment technique to be beneficial under one set of circumstances, and be harmful under another set of conditions.

The purpose of this paper is to explore various facets of responsibility in weather modification operations -- responsibility not only to the sponsors of weather modification projects, but to the general public as well. A review of prior weather modification activities will show the need for a mechanism to assure responsibility in weather modification operations. A means for meeting this need is proposed through identification of individuals qualified to conduct such operations in a professional manner.

II BACKGROUND:

Weather modification activity has increased markedly since 1961. Renewed interest at a federal level brought an expansion of weather modification activities which in turn has encouraged project development at local levels. A recent report (1) of weather modification activities in the United States for the fiscal year 1968 indicates that there were a total of 79 field operations conducted in 23 states affecting a total area of 11,383 square miles. These activities involved 44 different operators. The objectives of these projects include rain augmentation, snowpack augmentation, hail suppression, fog dissipation, experimental cloud modification, lightning suppression, atmospheric research, and severe storm modification. A measure of the amount of activity in the overall field is obtained from the fact that the total federal spending for fiscal year 1967 was approximately $10,000,000.

The method for selection of an operator (contractor) to conduct a specific weather modification project typically involves negotiations between the sponsor and one or more operators or firms to conduct the project. However, the guidelines for qualification of the operator typically have been vague. Attempts to answer the question of qualifications for experience, education and character have included specification of meteorologists, engineers, physicists and others, but a uniform definition of the requirements has not evolved.

The legal requirements for weather modification operations are presently the exclusive prerogative of the individual states. A recent report to the Weather Modification Association (2)

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shows that 34 states now have laws regulating weather modification activities. In most of these states a license or permit to operate is required for a weather modification project. A report of the operation and an evaluation of the results may be required by the state authorities. Many of the states require certain technical qualifications in order to be granted a license to operate. Financial ability to respond to damages for harm done is expressly stated or implied in most statutes. Penalties for noncompliance with state laws and regulations are also provided for.

In actual practice the specifics of the legal requirements frequently are not followed. The administrative experience of the states appears to consist mainly of receipt of applications and fees, and the issuance of licenses to conduct operations. Few guidelines have been set regarding limits of liability, specific qualifications of operators, and details of evaluation. Normally, these matters are left to the discretion of the responsible offices. These offices are more frequently than not, under-financed and under-staffed to administer and enforce their regulations fully. Their activities concerning weather modification are usually conducted incidentally to other conservation, engineering, water resources or agricultural programs.

Regulation of weather modification projects at the federal level consisted of a reporting and monitoring function by the National Science Foundation under authority of Congress in Public Law 85-510. This function was repealed in July 1968 by H.R. 5404 (known as the Daddario Bill). Currently, no federal regulatory or monitoring function exists other than on a voluntary basis.

III NEEDS:

The need for a mechanism to assume responsibility in weather modification operations is derived from two points.

First, since it is now known that beneficial changes can be accomplished under certain conditions by weather modification techniques, it seems a foregone conclusion that man will further develop his ability to manage the atmosphere much as he does other resources. For example, a recent report of a subcommittee on Science, Research and Development to the House Committee on Science and Astronautics concluded:

A. "The human race is, in fact, managing the environment today. The powerful forces of technology at our disposal give us capabilities to alter and control the populations of other species, and the natural resources of air, water, minerals and food supplies. The task of optimizing the use of the world to the benefit of man is inescapable. There is no retreat to a passive, non-interfering, Eden-like relationship with nature."

and again:

B. "The long-term support for civilization must be based on a farsighted management of a healthy productive worldwide environment. The two are incapable of separation."

Thus, it is apparent that the efforts to manage the atmosphere will continue, and a need exists for the establishment of operating requirements. The same Subcommittee Report (3) goes on to say:

> C. "An overall policy for the environment must be established which integrates these purposes and objectives and which provides for choice when they are incompatible....Choices are not always quantitative and trade-offs are not systematic.
>
> "It is mistakes in management, and not the concept of management, which should be our concern."

Second, no uniform requirement for assuring responsible weather modification activities exist at present. This function has been left to individual states.

Let us now consider the needs for assurance of professional conduct in weather modification operations from the viewpoints of the public, the sponsor, and the weather modification operator.

Consider first the needs of the general public. The public needs the assurance that full consideration is given to both benefits and disbenefits which might result from a particular operation. In other words, the public needs assurance that the operator has adequate knowledge and skill to maximize the benefits and to minimize the dis-benefits which might result from a particular weather modification project. The type of public concern for responsibility in weather modification activities is comparable to that which has led to licensing of professional persons dealing in medicine, law, or engineering.

Consider next the needs of the sponsor. The sponsor also has a need for assurance of responsible weather modification operations. Among the concerns of the sponsor is the need to know that the individual or organization selected has the experience and education to accomplish the desired modification objective. From an economic standpoint, the sponsor is concerned with the operator's ability, as a professional, to obtain the desired result at the least cost. Beyond this need, however, stands the need for protection from liability caused by the operator's activities which may result in damages. The production of severe disbenefits may result in a suit involving the sponsor no less than the operator. Suits involving damage claims invariably involve all parties concerned with a particular weather modification project. An example of such a case may be seen in the suit resulting from the December 1955 flood in California (4).

Consider next the needs of the operator. The operator probably has the greatest need for established standards. Primarily, he has a need for protection against claim for malpractice comparable to that needed in other professional practice, since it is becoming apparent that future weather modification litigation may be judged, in part, on the basis of operator negligence. A recent study conducted at the University of Arizona (5) provides some insight into the number and extent of the liability problems involved in weather modification. The most common protection from liability for the operator currently is insurance. This insurance is costly and often difficult to obtain. Substantial savings in both aspects could be achieved if reasonable standards for operators were established and applied in a uniform manner. These savings, of course, would also be reflected in reduced cost to sponsor.

Reasonable standards for weather modification operations can also provide for better services by the operator. The assurance that the activities conducted in a particular area are not being interfered with by another nearby operator, intentionally or through lack of ability, can lead to a better evaluation of the individual operator's effectiveness. The operator then obtains an economic benefit in terms of the ability to attract clients through proven ability. The cooperation of others operating in the field is also encouraged by reasonable standards of professional practice and ethics.

IV CERTIFICATION OF INDIVIDUALS FOR WEATHER MODIFICATION OPERATIONS:

A review of the discussion to this point will lead to several possible solutions to the problem. However, in view of current attitudes and the fact that the solution must fit a variety of state laws, one possibility appears to lend itself to the solution better than the others. This solution has as its basis the principle of dealing with the individual who is doing the work. In other words, one step toward solution of the overall problem is to insure that the individual operator has the required qualifications of education, experience and ethical standards. This is the approach that has been taken by individuals active in the field of weather modification.

In 1966, members of the Weather Modification Association (WMA) began a study of the need for insuring responsible operations. The result came in the form of a recommendation to establish a program to publicly recognize those members of the WMA who were, in the judgement of their peers, qualified to carry out field activities in weather modification. The members of the organization represent private, university, state and federal activities in the field, and are concerned with all aspects of the problem from cloud physics to seeding operations. Hence, the entire field is represented and involved in recognition of qualified operators.

The program of the WMA was established under the heading of "Certification." The objective of this certification came under the general purpose of the WMA of promoting the field of weather modification. In addition to the recognition involved for individual operators, the certification was designed to meet the need for guidelines for qualifications. Certification of individuals to direct weather modification field operations was based on character, knowledge and experience. Certification is made at the discretion of a Board composed of members of the Association.

Two categories of qualifications are specified in the certification procedure -- general and specific. General qualifications state that a minimum of two years' field experience at the professional level in directing weather modification operations or research will be required of all applicants, in addition to the specific requirements of education and experience discussed below.

The most obvious need at the time of establishment of the program involved those individuals who, by intent, modify atmospheric processes. Thus, the most obvious requirement was for familiarity with the problems of field design, instrumentation, operations and interfacing with the public. This qualification could only be met by experience gained first-hand in

the field. It is necessary that the applicant show not only an ability to cope with the technical problems but an ability to cope with financing, budgeting, safeguarding and public attitudes.

Specific qualifications are divided into three categories, and members of WMA may apply under any one of the three.

Category A requires eight years of experience in weather modification field operations or research. This category considers those individuals who have demonstrated their ability to conduct field operations by virtue of significant experience. The fact that they have continued to serve the field, coupled with their character, attests to their ability. The total experience requirement in this category combined with the general requirement is ten years.

Category B requires a college degree in engineering, mathematics or the physical sciences and two years' experience in weather modification operations or research. This category provides for those individuals who by virtue of training or experience in related fields, have become active in weather modification despite a lack of formal training in the field. Essentially, this category provides for the substitution of education in a related field for either experience or training in meteorology. It should be noted that the two years' experience required by this category are in addition to the two years under general qualifications; and, hence, the requirement amounts to four years of experience with two at a professional level.

Category C requires a degree in meteorology, or a degree in engineering, mathematics or the physical sciences which includes or is in addition to at least 25 semester hours of meteorological course work. Formal training in meteorology is given emphasis, and can, essentially, be substituted for most of the experience required in the other categories. Thus, the only experience requirement for those individuals with formal meteorological training is the two years of professional level experience in the general requirement.

Weather modification field operations experience is defined to be that which is involved in the organization, development, and actual conduct of field projects designed to effect a change in the weather. Actual field experience is stressed throughout the Certification since recognition for other types of meteorological and engineering work may be obtained at a professional level in other ways. None of these other "registration" procedures, however, recognizes the unique qualifications required for weather modification operations. "Professional level" as used in this context is taken to indicate a level of responsibility for direct supervision and conduct of field operations or substantial parts thereof.

The Certification Board of WMA consists of three members appointed by the President of the Association. Board members are appointed for three year terms on a staggered basis such that a new member is appointed each year. The member of the Board who has the longest tenure serves as chairman. While no written requirement exists for Board Members to be Certified, the requirement is implied.

Individuals who feel they are qualified and desire certification must follow a pre-determined procedure. This procedure is initiated by requesting an application form and instructions from the Secretary of WMA. The application form includes requests for personal, educational

and experience information. If education is used to qualify, the application must be accompanied by transcript from the appropriate college (s). The application must also be accompanied by a $25 fee to defray expenses involved in Certification. This fee is retained by the Association whether the applicant is accepted or denied for Certification.

Following receipt by the Secretary, each application is forwarded to the Chairman of the Certification Board who then records the date and time of application. Letters are sent to each of the three references given by the applicant, and references are requested to comment on the applicant's educational, experience, and character qualifications. A total of 45 days is allotted for the purpose of requesting information from references.

Copies are made of the applications and a rating sheet is attached to each copy. The copies are then transmitted to the individual Board members. Each Board member is required to rate the applicant on the basis of both professional and subprofessional experience, educational background and character. Separate items of these qualifications are considered and rating is accomplished on the basis of acceptable, unacceptable and additional information required. If additional information is felt to be required, the applicant is notified and further action on the application is withheld until the information is received.

Following the formal review, the Chairman of the Certification Board notifies the applicant of the decision of the Board. If the application is approved the Chairman of the Board issues a certificate which verifies that the individual has met the requirements for certification as an individual qualified to conduct field operations in weather modification. If, however, the applicant is unsuccessful, the individual may re-apply not earlier than one calendar year after notification of disapproval. Each subsequent application must again be accompanied by a $25 fee. It should be clearly understood that certification is accomplished at the discretion of the Board.

The certification of members of WMA is effective for a period of three years from the date of issuance. This certification may be renewed by submitting an application in writing prior to the expiration date. The renewal application must be accompanied by a $5.00 fee. Issuance of a renewal of certification by the Board is automatic provided no notification of a violation of the conditions of the original certification has been received during the period that it was effective.

Considerable thought was given to the procedure to be followed in those cases where actions by certified members which were felt to be undesirable or undeserving of high standards of professional practice had occurred.

It was felt to be necessary to insure such standards while providing protection for the rights of all individuals involved. If the Board recommends renewal of the certification after review of all the facts available, no further action is required. If, however, the Board does not recommend renewal, an appeal procedure is available should the applicant so choose. Upon request for appeal, the entire matter is presented for the consideration of the certified members in attendance at two successive meetings of the Association. It is to be assumed that both the plaintiff and the defendant can be available to present their individual cases at these meetings. Renewal is denied only if two-thirds of the certified members in attendance at the second meeting indicate by secret, written ballot that renewal shall be denied.

V SIGNIFICANCE

The significance of the certification described lies in its recognition of demonstrated ability in the field of weather modification. Each group involved in a particular weather modification project -- sponsor, operator, and the public -- has the assurance that the individual responsible for the particular activities which affect the atmospheric processes is considered to have the requisite qualifications of experience, education and character which will assure responsible operations. Since certification is accomplished by the individuals' peers, it can be assumed that a knowledge of the state-of-the-art has been considered in their actions.

While certification by the WMA is not required by law before an individual may conduct weather modification operations, it does provide a basis for judgement both by legal bodies dealing with licensing and by prospective insurors of operators. The establishment of qualifications required for field operators and procedures for the recognition of those so qualified should provide guidelines for anyone concerned with such activities.

VI CONCLUSIONS:

Weather modification activities may affect the general public as much or more than activities of other professional disciplines. The need for responsibility in weather modification activity to the general public and all others involved is obvious. One solution to this problem is to deal with the individual who is carrying out the work, by a program of certification of individuals considered to be qualified to conduct field operations which has as its basis professional standards. Such a program is currently being carried out by the Weather Modification Association. It warrants consideration as a basis for future regulatory activities to be carried out at various governmental levels.

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ELEMENTS OF A MODEL LAW
FOR
REGULATION OF WEATHER MODIFICATION

Richard A. Schleusener, Robert D. Elliott, Thais U. Johnson (WMA Ad Hoc Committee for Study on Elements of a Model Law)

1. It is recognized that economic benefits can be derived from weather modification which will benefit the people of the State. Operations, research, experimentation, and development in the field of weather modification shall therefore be encouraged. In order to minimize possible adverse effects, weather modification activities shall be carried out with proper safeguards, and accurate information concerning such activities shall be made available for purposes of regulation. Weather modification is declared not to be an ultra-hazardous activity, and the consequence of materials and substances being disseminated into the atmosphere pursuant to an authorized project shall not give rise to any cause of action by any party based upon the contention or concept that such use of the atmosphere constitutes trespass or involves an actionable nuisance.

2. Activities known as "weather modification" which are covered by the statute shall be defined. The definition should not be so specific that new methods or objectives of weather modification are excluded from coverage. We suggest the following definition of weather modification: Changes in the composition, behavior, or dynamics of the atmosphere which are artificially and intentionally induced.

3. A Board shall be established, consisting of members chosen mainly from private life who represent interests concerned with water resources as they affect agriculture and industry. In addition, there shall be at least one member possessing technical competence in meteorology or in a related scientific field. No member of the Board may be at the time of appointment an employee of a person or corporation engaged in commercial weather modification, a corporate officer or director of a weather modification corporation, a self-employed weather modifier, or anyone having a substantial financial interest in weather modification.

4. The manner in which the Board members shall be chosen, together with the term of their service, shall be defined.

5. The Board is empowered to issue licenses to modify the weather. No person or agency may modify weather without a license.

6. The Board shall require the applicant to submit proof of financial responsibility before a license is issued in order to give reasonable assurance of protection to the public in the event it should be established that damages were caused to third parties as a result of negligence in carrying out the project.

7. In issuing licenses, the Board shall establish qualifications for licensees. These qualifications shall be in keeping with the qualifications currently recognized by professional and scientific associations concerned with the field of meteorology and/or weather modification.

8. The Board shall establish a license fee within statutory limitations. The term of the license shall be one calendar year, and may coincide with the principal precipitation season.

9. The Board shall establish conditions for the renewal of a license. The Board may revoke a license should the licensee cease to meet license qualifications, or should the licensee violate the statute. Revocation may occur only after a hearing before the Board.

10. "Project" is defined as the performance of weather modification activities limited to a single geographical area, over a continuing period of one year or less.

11. The Board is empowered to issue permits regulating permissible areas and times of operation for a project. A separate permit must be obtained for each project. One licensee may not transfer a permit to another licensee. The Board shall issue a permit only after establishing that the project will provide economic benefits, or that it will enhance scientific knowledge. The Board may issue only one active permit at a time for activities in a given geographic area, so that no two licensees have overlapping project areas.

12. The terms of project permit may be modified by the Board subsequent to a public hearing.

13. After the licensee has secured a permit, and before beginning operations, he must publish a notice of intent to modify weather in the principal newspapers of the counties to be affected by the weather modification program. The notice should include the name of the licensee, his address, his license and permit numbers, the name of the project, the area to be covered, the duration of the project, its purpose, and the type of materials and methods to be employed. The notice should run for two successive weeks, and proof of notice should be furnished to the Board by the licensee.

14. A project permit may be granted by the Board without prior publication of notice by the licensee in cases of evident fire, fog, or drought emergency. In such cases, publication of notice shall be performed as soon as possible.

15. The Board shall establish standards for the keeping of generator operations logs and for the final reporting of the project.

16. Failure to file legally required reports, or late filings, may be cause of revocation of license. The Board shall establish procedures for revocation under this provision.

17. Records of weather modification projects which are in the possession of the Board shall be available for public inspection.

18. A summary of all current weather modification projects in the State, together with a general evaluation of them, should be prepared annually for the Board by a qualified individual or institution appointed for this purpose.

19. In order to perform functions necessary to carry out this statute, the Board may:

(a) establish minimum standards of weather modification activities;
(b) conduct studies, investigations, and hearings;

(continued on next page)

(c) establish advisory committees;
(d) represent the State, with the consent of the Governor, in all matters pertaining to inter-state, Federal-State, or other intergovernmental cooperation in weather modification activities.

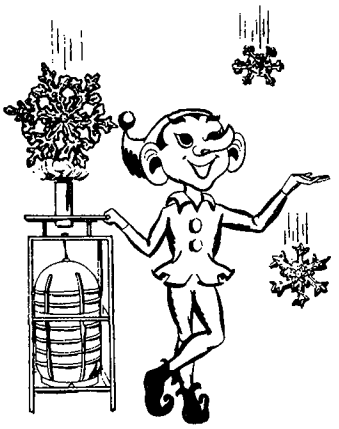
20. The Board should have the powers of a regulatory agency to hold hearings, hear complaints, and make determination of fact.

21. The financing of the Board shall be provided for from State funds.

22. The Board shall not engage in weather modification, either directly or by contract.

23. Penalties for violating this statute shall be defined.

24. Nothing in this statute shall be construed as acceptance by the State of liability for weather modification activities.



A WEATHER MODIFICATION COMMISSION

Merlin C. Williams *

Attempts to establish regulation of weather modification activities have been made with increasing frequency by governmental agencies at all levels. The degree of such activity has increased markedly during the past few years. Rivalries between agencies regarding which organization might gain control of an overall regulatory function have raised a great deal of speculation throughout the field. The reactions of those involved in the speculation has varied from staunch approval of a regulatory program to strong distrust of the motives behind the expressed desire to obtain the powers requested, particularly in view of the envisioned difficulties involved in such a task.

Traditionally, regulation of weather modification activities has been conducted by the individual states. These state laws provided broad latitude ranging from total control to a complete lack of control. In many cases, regulation by the states consists of accepting license fees, issuing licenses, collecting reports of the activities, with very little effective regulation. A number of reasons may be given for this situation not the least of which is the fact that the task of regulation has been assigned to existing state agencies without allocation of adequate funding or staffing.

Into the breach represented by this apparent lack of regulation have stepped several federal agencies with offers to accept the responsibility for a regulatory program. The efforts of some of these agencies have been quite persistent and long-term. In general, however, it should be noted that the agencies proposed also maintain active programs of one type or another in the field of weather modification. This is one of the factors that has caused concern to many individuals working in the field of weather modification.

The concept of a single agency that both regulates and operates weather modification projects raises not only doubts in the minds of many people, but outright opposition. Such a concept is tantamount to authorizing the Federal Communications Commission to build radio and television stations in competition with commercial interests, or having the Public Utilities Commission or Federal Power Commission build dams and sell electric power. Such activities would appear to be neither good governmental practice nor in the best interests of the field. This view is supported by individuals, private organizations and professional societies, (including Weather Modification Association) in a number of policy statements, some of which have been included in the Congressional Record.

What, then, is the alternate proposal to regulation by mission oriented agencies? Autonomy is hardly the answer to a field that is striving to develop responsible programs. The question of state regulation remains an open and unanswered one in view of the existing variety of state laws. The possibility that regulatory authority can be placed in an existing federal agency with the restriction that the agency be enjoined from further operations in weather modification seems rather remote.

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A proposal that has been made repeatedly in the past by individuals with considerable experience in the field involves the concept of an indemendent commission established at a federal level. Recently, this concept was formalized as a proposed act to establish a Weather Modification Commission by the Congress of the United States. The purpose of this Commission would be to provide a mechanism for a study of the needs for regulation of activities designed to manage the atmospheric water resources of the Nation.

The declaration of policy and objectives of the proposed act contains the following statements:

(a) It has been recognized that it is the policy of the United States to develop, encourage and maintain a coordinated, comprehensive, and long-range national program in atmospheric sciences for the benefit of mankind through precipitation augmentation, protection from severe storms, dispersion of fog, suppression of lightning and similar programs of management of atmospheric processes.

(b) It has been further recognized that it is the policy of the United States to provide for the protection and welfare of mankind through the regulation of those activities which specifically effect those processes vital to mankind's endeavors.

(c) Programs designed to affect changes in atmospheric processes (weather modification) should be designed on the basis of the most benefit with the least interference to normal activities of the general public. It is recognized that trade-offs of a responsible nature to produce such benefits will be required.

(d) The specific objective of this act is the establishment of a Weather Modification Commission.

The organization and functions of the Commission can be seen from the following descriptions from the proposed act:

(a) The Congress shall establish a Weather Modification Commission. The Commission will be composed of members representing federal and state governments, private industry and universities. The members will be selected on the basis of current experience in and knowledge of the field of weather modification. A total of nine members will be selected in a manner to provide for equitable representation of all areas of the United States and all interests involved. Thus, two commissioners will be selected from each of the following geographic regions:

> Those states wholly or partially west of the 100th meridian and north of the 40th parallel including Alaska.
>
> Those states wholly or partially west of the 100th meridian and wholly or partially south of the 40th parallel including Hawaii.
>
> Those states wholly east of the 100th meridian and wholly or partially north of the 40th parallel.
>
> Those states wholly east of the 100th meridian and south of the 40th parallel.

Commission members will further be selected to equally represent each of the following professional affiliations:

1. The Federal government
2. State governments
3. Private interests
4. The universities

No more than two members of the Commission will represent any one region or professional affiliation. The Chairman of the Commission will be appointed without regard to regional or professional affiliation, and based on his stature as a person with eminent leadership qualities and knowledge of the problems involved.

(b) The Commission will make a comprehensive investigation and study of the status of weather modification and the need for regulation of weather modification activities. The Commission will undertake the review of existing and planned weather modification activities in the United States in order to assess the need for regulation and coordination as set forth in the objectives of this act, including but not limited to the following:

1. Review the known and contemplated needs for natural resources from the atmospheric environment to maintain our national economy.

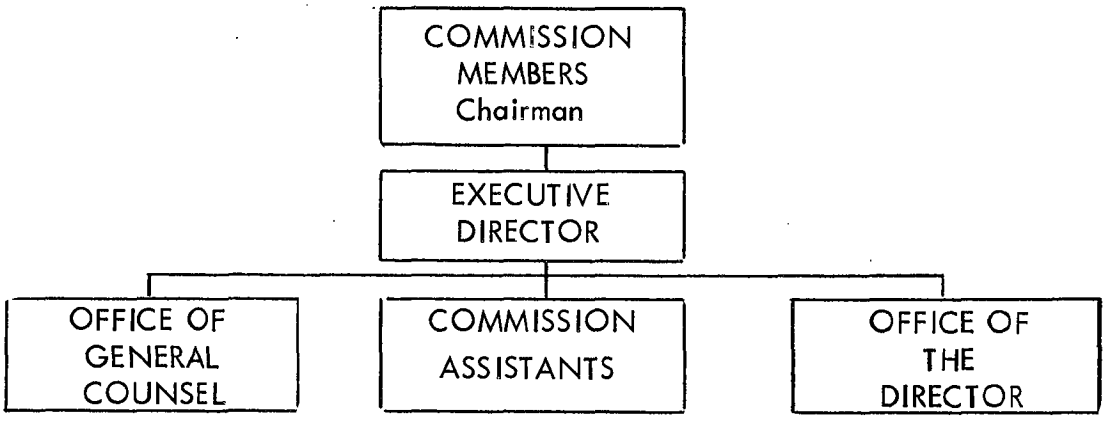
2. Review the existing surveys, applied research programs and weather modification engineering programs required to obtain the needed resources from the atmospheric environment to enhance human welfare and scientific knowledge.

3. Review the legal problems arising out of the management, use, development and control of the atmospheric environment.

4. Review the status of current regulation of weather modification activities at all levels of government.

5. Develop an organizational plan for a federally sponsored permanent Commission of the type described herein with estimated cost designed to conduct the regulatory and/or monitoring functions required.

(c) The organizational structure of the Commission is designed to provide the required surveys and studies within the time specified. The Commission shall appoint a staff composed of an Executive Director and staff assistants. The organization consists of the following:



The Chairman of the Commission shall be responsible for (1) the assignment of duties and responsibilities among such personnel and their continuing supervision, and (2) the use and expenditures of funds available to the Commission. In carrying out these provisions the Chairman shall be governed by the general policies of the Commission with respect to the work to be accomplished by it and the timing thereof.

(d) The Commission is authorized to secure directly from any executive department, agency, or independent instrumentality of the Government, any information it deems necessary to carry out its functions under this act; and each such department, agency, and instrumentality is authorized to cooperate with the Commission and, to the extent permitted by law, to furnish such information to the Commission, upon request made by the Chairman.

(e) The Commission shall submit to the Congress not later than two years after the establishment of the Commission as provided herein, a final report of its findings and recommendations. If it is determined by the Commission that adequate regulation of weather modification activities exist without formation of a permanent Commission as provided, the Commission shall cease to exist thirty days after it has submitted its final report.

International Cooperation

The Commission shall investigate the need for international cooperation in the regulation of weather modification, and make recommendations for a program to carry out such cooperation pursuant to agreements made by the Congress.

Reports

(a) The Commission shall transmit to the Congress in January of each year a report, which shall include:

1. A comprehensive description of the activities and the accomplishments of the Commission during the preceding fiscal year, and

2. An evaluation of the activities and accomplishments of this Commission in terms of the objectives set forth pursuant to this act.

(b) Reports made under this section shall contain such recommendations for legislation and funding as necessary or desirable for the attainment of the objectives of this act during succeeding fiscal years.

It should be noted that the proposed act contains provisions for the elimination of the Commission at the end of two years if it is determined that additional regulation beyond the current levels is not required. It should be further noted that the two year period of study will provide ample opportunity for those engaged in weather modification to make their desires known to the Commission. It is to be assumed that the Commissioners would consider the interests of all individuals and groups in the formulation of the requirements for regulation.

It must be recognized that the proposed act to establish a Weather Modification Commission has its weaknesses and faults. It appears to be, however, in the tradition of democratic practice in that it provides for representation and separation of regulation and operation. For these reasons it is felt that support for this concept of a Weather Modification Commission is justified.

CONSTITUTION AND BY-LAWS OF THE WEATHER MODIFICATION ASSOCIATION

ARTICLE I. NAME

The name of the organization shall be the WEATHER MODIFICATION ASSOCIATION.

ARTICLE II. PURPOSE

The Association shall function as a non-profit organization. Its purpose is to assist in the development of weather modification by activities associated with weather modification which should include, but are not limited to the following:

a) Promotion: Promoting research and engineering advancements.
b) Publication: Ascertaining, disseminating, and publishing information on new developments and trends.
c) Standard of Conduct: Encouraging and promoting the highest standards for professional conduct.
d) Public Relations: Increasing public understanding of the aims of those working in the various fields of weather modification.
e) Insurance: Assist in arranging liability insurance upon application from members performing field operations or experiments.
f) Certification: Certifying individual members qualified to execute field experiments or operations in weather modification.

ARTICLE III. MEMBERSHIP

A. Classes of Membership:

There shall be four (4) classes of membership.

1. Member: Any person who subscribes to the statement of purposes of the Association upon payment of annual dues shall be afforded the privilege of membership. Members of the Weather Control Research Association shall become members of the Westher Modification Association upon adoption of this constitution.
2. Associate Corporation Member: Any organization with an interest in weather modification, but with no current program, upon payment of dues and subscription to the statement of purposes of the Association shall become an Associate Corporation Member.
3. Corporation Member: Any organization with active programs in weather modification, upon payment of dues and subscription to the statement of purposes of the Association, shall become a Corporation Member.
4. Honorary Member: Open to former members who have made an outstanding contribution to any phase of weather modification. Honorary membership shall be subject to the unanimous consent of the officers of the organization.

B. Privileges of Membership:

1. Member: Each member shall have the right to vote in business of the Association as specified in this Constitution and shall have the right to hold any office.
2. Associate Corporation Members: May send observers to meetings but shall have no vote in the business of the Association.
3. Corporation Members: May designate one (1) individual to act for the organization in the affairs of the Association. This individual shall have the same rights and privileges as a Member.
4. Honorary Members: Shall have the same privileges as Members.

ARTICLE IV. DUES

All dues shall be paid on a calendar year basis. Annual dues shall be set for all classes of membership by the Executive Committee specified in Article VI. Changes in annual dues shall be approved by a majority vote of the membership. Dues for 1968 shall be as follows:

Member	$ 12.00
Associate Corporation Member	24.00
Corporation Member	100.00
Honorary Member	None

ARTICLE V. CERTIFICATION OF MEMBERS

Certification of individual members as being qualified to execute field experiments or operations in weather modification shall be based upon experience, knowledge, and character. Certification shall be accomplished by the unanimous vote of a Certification Board which shall be composed of three (3) Certified Members who shall be appointed by the President. The members of the Certification Board shall each serve three (3) years on staggered terms. Changes in procedure for certification of members shall be made only after affirmative majority vote of the Certified Members present at any annual meeting.

ARTICLE VI. ADMINISTRATION

The administration of the Association shall be vested in the Executive Committee. The Executive Committee shall consist of the elected officers: President, President-Elect, Secretary, and Treasurer; and three (3) elected trustees who shall serve staggered three-year terms. The Trustees shall represent, respectively, private groups, university groups, and government groups. Following an initial election to fill all offices, an election shall be held at the annual business meeting to elect the President-Elect, Secretary, Treasurer, and one (1) Trustee.

Nominations for elective offices shall be made by nominating committee appointed by the President. Nominations for offices may be made from the floor at the time of the annual meeting.

No person shall serve more than two (2) consecutive terms in any office.

ARTICLE VII. MEETINGS

General meetings shall be held annually.

Special meetings may be called by the Executive Committee. Advance notice of all meetings shall be mailed by the Secretary to all members at least 30 days prior to the date of the meeting.

Business meetings will be held concurrently with the annual meetings. The presiding officer and 10 percent of the voting members shall constitute a quorum. The location and date of all meetings shall be determined by a majority vote of the Executive Committee.

ARTICLE VIII. DUTIES OF THE PRESIDENT

The President shall be responsible for the administration of the organization. He shall appoint such committees as he deems necessary for the successful accomplishment of the organization's aims. The President shall preside at all meetings and shall be a member ex-officio of all committees. In the absence of the President, the President-Elect shall preside. In the absence of both the President and President-Elect, the Secretary shall preside.

ARTICLE IX. DUTIES OF THE SECRETARY

The Secretary shall be responsible for the minutes of each meeting and shall see that all members are notified of meetings.

ARTICLE X. DUTIES OF THE TREASURER

The Treasurer shall conduct the financial affairs of the Association and keep an accurate record thereof.

ARTICLE XI. REFERENDUMS

A referendum on any proposal may be initiated by the Executive Committee or any five (5) members at large. The voting on any question, including removal of officers, shall be conducted by the President among the eligible voters, except that if the removal of the President is proposed, the President-Elect shall conduct the voting. A court consisting of the President, President-Elect, and Secretary shall consider any dispute on procedure and its decision shall be final.

ARTICLE XII. AMENDMENTS

This Constitution and By-Laws may be amended at any regular or special meeting by an affirmative vote of two-thirds of the members present or by a majority vote of all members by written ballots.

ARTICLE XIII. ADOPTION OF CONSTITUTION AND BY-LAWS.

This Constitution and By-Laws shall be adopted by the affirmative vote of a two-thirds majority of the members attending any regularly constituted meeting of the Weather Control Research Association and shall become effective at the time of the first following annual meeting. All assets of the Weather Control Research Association shall be transferred to the Weather Modification Association.